CROSS COMPATIBILITY ANALYSIS FOR PRODUCTION OF HYBRIDS IN *Anthurium andreanum* Linden

MADHU KUMAR, K.

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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695 522

DECLARATION

I hereby declare that this thesis entitled **"Cross compatibility analysis for production of hybrids in *Anthurium andreanum* Linden"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
8-1-2010.

K. Madhukumar

Madhu Kumar, K
(2006-21-107)

CERTIFICATE

Certified that this thesis entitled **"Cross compatibility analysis for production of hybrids in *Anthurium andreanum* Linden"** is a record of research work done independently by **Mr. Madhu Kumar. K (2006-21-107)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mayadevi.P

Vellayani,
8-1-2010.

Dr. P. MAYADEVI
(Chairperson, Advisory Committee)
Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

APPROVED BY

Chairperson:

Dr. P. MAYADEVI
(Chairperson, Advisory Committee)
Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Mayadevi P
8-01-10

Members:

Dr. D.S. RADHA DEVI
Professor and Head,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Radhadevi
8/01/10

Dr. V.L. SHEELA,
Professor,
Department of Pomology and Floriculture,
College of Agriculture, Vellayani,
Thiruvananthapuram. 695 522

Sheela.V.L
8.01.10

Dr. VIJAYA RAGHAVA KUMAR,
Professor and Head,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram. 695 522

Vijaya Kumar
08/01/2010

Dr. R. V. MANJU ,
Assistant Professor, (Sr. Scale),
Department of Plant physiology,
College of Agriculture, Vellayani,
Thiruvananthapuram. 695 522

Manju R V
8/1/10

EXTERNAL EXAMINER

S. R. Khadiwan
08/01/10.

Dedicated to

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Madhu Kumar. K

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LIST OF ABBREVIATIONS

^{0} C	Degree Celcius
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
AW	Acropolis White
C	Carrie
CD	Critical difference
cm	Centimeters (s)
cv.	cultivar
CV	Ceasor violet
df	degrees of freedom
DT	Dragon's Tongue
E	Esmeralda
et al.	and others
Fig.	Figure
FR	Fla Red
g	Gram(s)
GCV	Genotypic coefficient of variation
HR	Honeymoon Red
i.e.	That is
KO	Kalimpong Orange
KR x LR	Kalympong Red x Liver Red
LJ	Lady Jane
LR x PR	Liver Red x Pompon Red
LR	Liver Red
ml	Millilitre
MO	Mauritius Orange
MSE	Error mean square
NO	Nitta Orange
NO x DT	Nitta Orange x Dragon Tongue

LIST OF ABBREVIATIONS CONTINUED

OG	Orange Glory
OG x DT	Orange Glory x Dragon Tongue
PCV	Phenotypic coefficient of variation
PR	Pompon Red
PR x DT (1)	Pompon Red x Dragon Tongue (1)
PR x DT (2)	Pompon Red x Dragon Tongue (2)
PR x FR	Pompon Red x Fla Red
PR x LR	Pompon Red x Liver Red
PR x OG	Pompon Red x Orange Glory
SS	Sum of squares
viz.	Namely
W x LJ	White x Lady Jane

Introduction

1. INTRODUCTION

Cut flowers constitute 45 per cent of the total world trade in floriculture products. India grows various types of subtropical and tropical flowers. However cut flower export from India is negligible. The market for tropical flowers in the global trade remains unsaturated. Cut flower export offers India a valuable avenue for earning foreign exchange.

The global trade in anthurium is estimated to be 60 million US$ with annual increase of 10%. The Netherlands is the leading producer of anthurium cut flowers with their domestic production of 37 million stems, grown on 70 hectares of land under glass houses valued at 49.5 million Netherland guilders. Mauritius grows anthuriums in 60 hectares with a production of 12 million stems/ year and exports Rs.70 million worth of cut flower stems. It is the national flower of Mauritius and the country is the second largest producer and exporter of anthurium. West Indies grows anthurium in 40 hectares of land and produces 4 million stems. Until 1970, Hawii was the worlds leading producer and exporter of anthurium flowers. In the last a few decades, the Hawaiian anthurium industry declined because of bacterial blight. Anthurium is also produced commercially in Thailand, Singapore, Indonesia, Japan, South Korea, Sri Lanka, Taiwan and Philippines (Rajeevan and Valsalakumari, 2000, Shiva and Nair, 2008b and Sheela, 2008).

Anthurium andreanum is one of the important commercial cut flower crops of the world. The cultivation of this crop has recently been identified as a thrust area of Indian agriculture. The Government of India has identified Kerala as the product specific Intensive Floriculture Zone for anthurium and Orchids. The central Government also announced the creation of nine model floriculture centres in nine states of the country. One centre for anthurium and orchid is proposed to be set up at Thiruvananthapuram. Anthurium is an exotic floricultural plant well suited

for large scale cultivation under the humid warm conditions prevailing in Kerala. Efforts have started for its wide spread cultivation in both urban and rural areas of the state. In several centers in the state voluntary agencies have now started sponsoring such programmes. The newly formed Federation of Indian floriculturists is a pioneering effort in this direction.

Anthurium constitute the largest genus of the family Araceae, constituting more than 700 species. The name Anthurium means tail flower in Greek (anthos-flower, aura-tail). Two species of the genus with commercial importance are *Anthurium andreanum* Linden (oil cloth flower, tail flower or palette flower) and *Anthurium scherzerianum* (Flamingo flower or flame plant) both of which have magnificent flowers and attractive foliage.

Anthuriums are semi terrestrial and perennial epiphytic plants with creeping arborscent stem. The popular anthurium flower is actually a compound inflorescence called spadix. The anthurium flower consists of a colourful, shiny, heart shaped modified leaf (spathe) surrounding a straight or slightly curved inflorescence "candle" (spadix). The greatest advantage of anthurium is that it produces flowers all round the year. They can be easily fitted into the agro- climatic and socio-economic situation of Kerala.

Anthurium requires a warm green house (18°-28°C) with shading (75 per cent) and a humid (75 per cent) condition. It is a very slow growing plant with a long juvenile phase taking about 2 ½ - 3 years to reach first flowering and the floral characters stabilize only after one more year. The annual flower production ranges from 5- 6 spadices per year. Mature plants also produce vegetative suckers one or two per plant per year. The income from anthurium crop depends on the number of suckers and the flower that produced by plant annually. If the frequency of their production can be increased, income can be increased.

The best known species is *Anthurium andreanum* Linden, which was discovered by Eduard Andre in 1870 during his travels to Columbia and Ecuador. *Anthurium andreanum* is a native of South-West Columbia which was brought to Europe in 1876 (Singh, 1987). From Europe the species spread to Brazil and Hawaii.

Anthuriums were introduced in India via England by coffee and tea planters who wanted showy exotic plants for their bunglows. The coastal belts of South India, Eastern and Western Ghats and North- eastern hilly regions having high rainfall and relative humidity are highly suitable areas for growing anthuriums. A few growers in Yercaud, Salem district of Tamil Nadu, Bangalore and Coorg region of Karnataka, Cochin and Thiruvananthapuram of Kerala, Kalympong of West Bengal, Pune and Nasik have started growing anthuriums on a large scale for cut-flower production (Singh, 1995, Shiva and Nair, 2008b and Sheela, 2008).

Inflorescence of Anthurium is a spadix which comprises of a brightly coloured spathe showing tremendous variability in size, shape, colour and texture and a thin flower bearing spadix. The value of the plants depends on the size and colour of the spathe and spadix. The present day cultivars are introduced mainly from Holland, Hawaii and other countries (Shiva and Nair, 2008b). The cost of planting material is the major component of establishment cost, which accounts for about 71-78% (Gajanana and Subrahmanyan, 2003).

The anthurium cut-flower production in India is still in its infancy due to lack of elite planting materials, standard cultural practices and adequate infrastructure for marketing. It is only very recently that anthurium flowers are seen in the Indian florists shops. At present the practice followed by floriculturists of Kerala is to buy planting materials imported from Holland by some agencies at exhorbitant prices and naturally this has limited their capacity of cultivating anthurium profitably in large scale. Moreover in the view of GATT agreement and other

restrictions, this import of planting material will soon become obsolete in the coming years. The two important constraints faced by the prospective growers for commercial cultivation in Kerala are the lack of suitably adapted planting materials with international commercial qualities at reasonable prices and the absence of a stable and steady market for the sale of flowers. The constraints can be solved if plant breeders seriously take up anthurim breeding to produce our own novel and suitably adapted hybrids that possess the necessary qualities to compete in the international market. These new hybrids can then be mericloned for distribution to growers at reasonable price.

Together with some of its many hybrids *Anthurium andreanum* today forms the basis of a substantial cut flower industry chiefly in Hawaii, where much research is done in its hybridization and cut flower (Kamemoto, 1981 and Sheela, 2008).

The cultivated forms are probably derived from inter specific hybrids which are supposed to have arisen spontaneously in the early anthurium collections (Birdsey, 1951). Anthurium improvement by interspecific and intraspecific hybridization has led to the development of valued colour forms of spathe. There is an abundance of genetic variability in some species of *Anthurium* as revealed by the Karyotype analysis and meiotic studies by Lalithambika (1978) and Satyadas (1985). These facts point out the possibility of achieving crop improvement in *Anthurium* through hybridization and selection.

Hybridization followed by selection is the accepted method used for improving anthuriums (Kamemoto and Nakasone, 1955, Sheffer and Kamemoto, 1976, 1977, Maurer, 1979 and Henny et al., 1988). This is being practiced in leading anthurium countries of the world such as Netherlands, Mauritius, Hawaii, Philippines, Srilanka etc. Hybridization between selected varieties with good combining ability can be used for creating valuable *Anthurium* hybrids with desirable plant characters such

as compact plant type, medium sized leaves, heart shaped spathe with symmetrical lobes, wrinkled spathe texture, straight long inflorescence axis and a reclining spadix to facilitate packing (Mayadevi, 2001).

Hybridization done discretely between selected parents with good combining ability can yield valuable and novel new hybrids. Anthurium, is a naturally cross fertilized crop and thus has great genetic potential which is yet to be exploited. A number of new anthurium hybrids have already been developed in this department through intervarietal hybridization among some popular semicommercial varieties. Genetic improvement of these selected hybrids and production of more new hybrids can go a long way in increasing productivity and popularization of this important crop in Kerala. Hence generation of more hybrids with marketable commercial qualities which can be developed into new varieties is envisaged in this project.

With the above background taken with due consideration the present study is undertaken with the aim of assessing the genetic variability of 40 genotypes of *Anthurium andreanum* to identify suitable parents with commercial qualities and to determine the cross compatibility among the selected parents. The hybrids obtained from the compatible crosses will come to bloom within a time span of three to four years and desirable types can be selected from the lot.

Review of Literature

2. REVIEW OF LITERATURE

Anthurium is currently being promoted as an export oriented cut flower suitable for commercial cultivation in Kerala. The only species of commercial value in tropics is *Anthurium andreanum* which is a native of South West Columbia. The warm humid tropical climate of Kerala can be easily adapted for its widespread cultivation.

Hybridization followed by selection is the best method to achieve crop improvement in anthurium. The crop is highly heterozygous with great genetic potential which is yet to be exploited. So the present study was initiated to improve specific commercial characters in anthurium. A review of the works relevant to the study are attempted here.

2.1 Cultivation Aspects

Anthuriums require a warm green house with 75 per cent shading from direct sunlight and atmospheric humidity of 70-80 per cent. The temperature range is between 25 and 28°C during the day and 18 and 22°C during the night with optimum being 22° to 25°C. The relative humidity is also very important for growth and development of anthurium, the optimum being around 75 per cent. The morphological characters, flower production and quality of flowers are affected by the intensity of light. The optimum shade requirement is 75 per cent (Mercy and Dale, 1994).

Anthurium needs a light, well drained medium rich in organic matter and with good aeration and water holding capacity. They are usually grown in a medium consisting of sand, cow dung, brick pieces, charcoal and coconut husk which provide 100 per cent drainage (Mercy and Dale, 1994). Being shade loving tropical plant, it requires temperature ranging from 21-24 °C duringday and 18.3 °C during night, high atmospheric humidity (50 – 80 per cent), low to medium light intensity (2,000 - 6,000 lux) and 60-80% shade for luxuriant growth and flowering (Prasad et al., 2001 and Prakash et al., 2006)

Srinivasa (2006 b) conducted a field trial to study the influence of different shade levels on the growth and flowering of anthurium cv. Honduras. The results revealed that all the vegetative and reproductive characters recorded maximum values at 80 per cent shade level.

Dhaduk et al. (2007) reported that GA_3 application (500 ppm) in the form of foliar spray is highly beneficial for improving growth and flowering in different cultivars of anthurium. Application of GA_3 as foliar spray induces increase in plant height, Number of leaves per plant and leaf size and improves flowering with increased number of flowers per plant and spathe size.

Anthuriums prefer to grow under shade. The tolerable level of light in the tropical region during summer is 20-30 per cent. Excessive light causes yellowing and scorching of leaves. Very low light intensity causes excessive vegetative growth and low flowering. It is preferable to grow anthurium in the open, under artificial shade structures for better growth and yield. Plant prefer to grow under a relative humidity of not less than 60 per cent and a temperature of not more than 30°C (KAU, 2007).

The total number of leaves produced ranged from 5.00 (FYM + Brick piece) to 7.66 (FYM + Cocofibre). Maximum value of leaf lamina diameter (20.40 cm), leaf sheath length (24.40 cm), plant height (48.73 cm), early flower initiation (206.33 days), maximum number of spadices (4.66), largest flower (33.60 cm^2) and longest flower stalk (31.20 cm) were recorded in FYM + Cocofibre. FYM + Cocofibre were an efficient alternate substrate for anthurium cultivation. (Keshav and Prashant, 2008).

2.2 Nutrition

Colour break down of spathe tissue of anthurium is a typical symptom of Calcium deficiency. Calcium application significantly reduced this disorder (Higaki et al., 1980).

A. andreanum cv. 'Lady Jane' was grown with a weekly application of 20:20:20 NPK fertilizer at 200, 400, 600 and 800 mg l^{-1}, and the study showed

that plant growth was best at the lower two fertilizer levels. Higher levels were found to be detrimental (Henny and Fooshee, 1988).

Studies in the Kerala Agricultural University (Salvi, 1997) revealed that application of NPK fertilizer complex of 17:17:17 @ 1 per cent at weekly intervals produced the maximum height and increased other biometrical characters in *A. andreanum* cv. 'Hawaiian Red'.

Srinivasa (2006 a) conducted a study to determine the effects fertilizers on the growth and flowering of *Anthurium andreanum* cv. Chaco. Maximum leaf length (17.63 cm), leaf width (8.52 cm), number of suckers (1.88), stalk length (37.31 cm), spadix length (5.00 cm), spadix girth (6.04 mm) and number of spadices (2.25) were recorded in split application of 30:20:40 g NPK. Split application of 20:15:30 g NPK produced significantly maximum spathe length (9.88 cm) and spathe width (7.81 cm). Physiological parameters (chlorophyll, carotenoids, anthocyanins and wax) did not differ significantly among different fertilizer levels.

An experiment conducted to study the effects of integrated nutrient management (INM) practices in improving the flower yield of *Anthurium andreanum cv.* Meringue revealed that the treatment combination of 4 per cent Panchagavya + 5per cent RDF favourably influenced plant height (32.40 cm), number of leaves per plant (6.20), days to first flowering (206.50), number of suckers per plant (4.20) and flower yield per plant (5.90). The number of aerial roots per plant (2.60), number of primary roots per plant (12.50) and root length (15.30 cm) were also the best in the same treatment (Waheeduzzama et al, 2007).

2.3 Morphological and Floral Characters

2. 3.1 Plant Height

Tisdale et al. (1985) reported that plant height can be used as an index of plant growth. Higaki and Imamura (1988) found that the height of plants gradually decreased with increasing pH upto eight.

Bindu and Mercy (1994), observed that the five varieties of the genus of *Anthurium* studied by them showed significant variation in plant height ranging from 45 cm in the var. 'Lady Jane' to 85 cm in the var. 'Pink'. Sindhu (1995) recorded the height of six varieties of *Anthurium andreanum* which ranged from 43 cm. to 70 cm. In another study with 'Hawaiian Red' Abdussammed (1999) concluded that nutrients significantly influenced plant height both in ground and pot planting.

Renu (2000) recorded significant variation in plant height ranging from 29.7 cm in var. 'Midori Green' to 70.9 cm in 'Pompon Red'. The var. 'Liver Red' and 'Mauritius Orange' also were tall, with heights almost on par with that of the var. 'Pompon Red'.

Mayadevi (2001) recorded the height of 20 varieties of *Anthurium andreanum* which ranged from 45.5 cm in var. 'Midori Green' to 96.67 cm in var. 'White'. The height of the genotypes varied from 22.17 cm to 64.80 cm in the study conducted by Asish (2002). Premna (2003) observed a plant height of 21.25 cm ('Carre') to 44.00 cm ('PR x DT').

Talia et al, (2003) recorded the height of six new cultivars Carnival, Neon, Queen, Santè, Terra, and Vanilla in soilless culture and under heated glasshouse conditions. Differences were observed in stem height, with Queen the longest (averaging 53 cm) and Santè the shortest (31 cm on average).

Pravin (2004) in his study with 14 genotypes of anthurium found significant variation in plant height and it is ranged from 30.80 cm in NO x DT to 76.17 cm in Liver Red. The mean plant height observed was 47.81 cm.

Srinivasa and Reddy (2005) conducted an experiment to evaluate the performance of anthurium cultivars Hondura, Tinora, Senator, Tropical and Pasricha for cut flower production. Out of these varieties Honduras recorded the maximum plant height (40.94 cm),

A comparative trial on six *Anthurium* (*Anthurium andreanum*) cultivars for cut flower production (Cheers, Choco, Cognac, Pistacea, Premier and Simba)

cultured by the soilless technique by Cristiano et al, (2007) observed differences in stem height, with Cheers the longest (averaging 72 cm) and Choco the shortest (56 cm on average).

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and recorded significant variations in plant height ranging from 4.27 cm in Taurus to 9.22 cm in Mirage. Among the cultivars maximum plant height was shown in Mirage followed by Honey and Wrinkle Orange.

2. 3.2 Leaf Size/Leaf Area

Medium sized leaves is considered best for an ideal commercial anthurium plant type as plants with medium leaves are more compact and occupy less green house space than those with large spready leaves.

Sheffer and Kamemoto (1978) made crosses between *Anthurium scherzerianum* and *Anthurium wendlingerii* and produced a hybrid and observed the leaf size of parents and hybrids for comparison and found that the length and position of leaf blade were intermediate between the highly contrasting characters of the parental species. Among the five varieties of *Anthurium andreanum* studied by Bindu (1992) the length of leaves ranged from 13.5 to 26 cm. Leaf size was maximum for 'Pink' and minimum for 'Lady Jane' and 'Chilli Red'.

Mercy and Dale (1994) were of the opinion that the leaves of commercially valuable floral anthurium should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves indicated premitiveness and were undesirable. Sindhu (1995) observed that the var. 'Pink' produced bigger sized leaves whereas 'White' and 'Chilli Red' produced smaller sized leaves which are commercially more valuable than 'Pink'.

Salvi (1997) with the variety 'Hawaiian Red' reported that leaf length and breadth were significantly influenced by shade and growth regulators. The treatment combination 60 per cent shade + Hoagland solution + 750 ppm BA

produced the longest leaves (10.50 cm) while 60 per cent shade + fertilizer complex + 750 ppm BA produced the broadest leaves (8.00 cm). Abdussammed (1999) reported that the leaf length, breadth and leaf area were not influenced significantly by the nutrients either in ground or in pot planting.

Mayadevi (2001) inferred that the var. 'Chilli Red' had the least leaf area (66.26 cm^2) followed by var. 'Kalympong Red' (66.92 cm^2). 'Honey moon Red' had the largest leaf area of 88.89 cm^2 which is not ideal.

Leaf area ranging from 41.32 to 323.77 cm^2 was reported by Asish (2002) in his study with 50 genotypes. Premna (2003) recorded a minimum leaf area for the genotype 'Carre' (113.62cm^2) and a maximum for 'Acropolis White' (301.10 cm^2).

Among the 14 varieties of *Anthurium andreanum* studied by Pravin (2004) the leaf area varied according to the size of the leaf and it was ranged from 91.97 cm^2 in PR x FR (1) to 287.76 cm^2 in LR x PR.

Silva et al, (2008) conducted a study to determine which among leaf length (C), leaf width (L) or C x L is more appropriate for estimating the leaf area of anthurium (*Anthurium andreanum* cv. Apalai) using a linear regression equation, and to compare the performance of different regression functions. The parameter that estimated the leaf area of anthurium with the least error was C x L, recording a coefficient of variation of 0.99. Linear functions were adequate in the estimation of the leaf area of anthurium.

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and found that leaf size and leaf area were maximum in Honey. Among the genotypes leaf size ranged from 2.95 to5.36 cm while leaf area ranging from 5.33 to 16.43 cm^2.

2. 3.3 Internode Length

Singh (1987) reported that a desirable anthurium should produce short internodes inorder to limit the height of the plant.

Mercy and Dale (1994) were of the opinion that a commercial variety should have simple leaves borne singly on long stalks with sheathing bases in a spiral rosette with very short internodes so that the plant has a compact bushy appearance.

Mayadevi (2001) recorded the internode length of five parents and ten F_1 hybrids. Mean internode length ranged from 1.00 cm ('Pink') to 1.52 cm ('Liver Red') among the parents and in the hybrids it ranged from 1.02 cm ('P x CR') to 1.34 cm ('HR x P').

Asish (2002) recorded that internode length ranged from 0.97 cm in 'MW x PR' to 2.57 cm in 'MW x FR (1)'. Premna (2003) observed a maximum value of 1.48 cm ('PR x DT' and 'Acropolis White') and a minimum of 1.20 cm ('Carre'). The mean internode length was 1.20 cm with a range of 0.93 cm in MO x KR (1) to 1.63 in LR x PR (Pravin, 2004).

2. 3.4 Number of Suckers per Plant

Suckering is a natural method of vegetative propagation in anthurium and the ability to produce suckers is a very desirable attribute for commercial varieties.

Higaki and Rasmussen (1979) observed that some cultivars produced basal suckers readily while others had to be stimulated to produce suckers by foliar application of N-6 Benzyl adenine at 1000 mg l^{-1}.

Mercy and Dale (1994) reported that propagation of anthurium using suckers was a very slow and undependable process because most of the good commercial and hybrid varieties were very shy suckering or did not sucker at all. 'Pink' is a profusely suckering variety but is not commercially valuable. Foliar spraying with Gibberellic acid (GA3) or Benzyl adenine (BA) (500-1000 ppm) was found to increase sucker production. Sindhu (1995) observed maximum number of suckers in the variety 'Pink' and the least in the variety 'Kalympong Red'.

Salvi (1997) inferred that a treatment combination of 80 per cent shade and 750 ppm BA was the best for maximising sucker production. Abdussammed (1999) reported that nutrients fail to make any significant influence on the number of suckers produced per plant, but application of growth regulators increased the sucker production in *Anthurium andreanum* significantly.

Among the ten varieties of anthurium studied by Renu (2000) it was seen that sucker producing ability is an important trait considered in the selection of superior types. It was very high for varieties 'Liver Red', 'Lady Jane' and 'Ceylon Red' ('Fla Red'), medium for 'Midori Green', 'Mauritius Orange' and 'Nitta Orange', low for 'Merengue White' and 'Dragon's Tongue Red' and very low for 'Pompon Red' and 'Tropical Red'.

Mayadevi (2001) while studying 20 varieties of Anthurium observed maximum number of sucker production for varieties 'Pink' and 'Lady Jane' (4) followed by 'Liver Red', 'Honeymoon Red' and 'Kalympong Orange' (3.67, 3.67, 3.33). Very few suckers were produced by varieties 'Nitta Orange', 'Merengue White' and 'Tropical Red'.

Asish (2002) with 50 genotypes observed a range of 1.00 in 'MW x DT', 'MW x FR (2)' and 'DT x KR' to 3.00 in 'LR x FR', 'HR x LW' and 'LJ x MW'. Among 14 genotypes studied by Premna (2003) the sucker production was highest for the genotype 'OO x KR' (2.25) and lowest for 'Acropolis White' (0.25).

Pravin (2004) reported that among the varieties studied, suckering was very high for Liver Red (4); low for KO x CR and PR x KR and nil for FR x MW (1), Acropolis White and Tropical Red.

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house. They observed maximum number of suckers in Mirage and the cultivars Mirage, Agnihothri and Deep Pink were found suitable for sucker production.

2. 3.5 Number of Leaves/Spadices per Plant

Morphological studies conducted by Christensen (1971) showed that *Anthurium andreanum* had a long juvenile phase of vegetative growth followed by a generative phase in which flower buds were produced.

Higaki and Poole (1978) while studying the var. 'Ozaki' found that the flower production increased with age of the plant. Higaki and Rasmussen (1979) found that anthuriums are slow growing, producing only 6-8 new leaves and vegetative buds on a stem axis per year.

Singh (1987) reported that the most commonly cultivated varieties produced flowers all round the year at the rate of one flower from each leaf axil. The sequence of leaf, flower and new leaf was maintained throughout the life of the plant.

Mercy and Dale (1994) observed that anthuriums are slow growing and produced only five to eight new leaves on a stem axis per year and generally with each new leaf, a root also emerged. Sindhu (1995) has recorded that the number of spadices produced annually by an anthurium plant varied from 4 to 8. Renu (2000) showed that one spadix each was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant was the same. The annual production of leaves or spadices was the highest in 'Lady Jane' (7.6) followed by 'Liver Red' and 'Pompon Red'.

Mayadevi (2001) reported that among the varieties studied, 'Honeymoon Red' has the highest number of spadices (7.6). She also stated that the average production ranged from 4.67 to 8.00. Asish (2002) observed that, among 50 genotypes he studied, maximum number was observed in KO x DT (7) while the minimum in 'PR x DT' and 'TR x MW(3)'.

Eight *Anthurium andreanum* cultivars, AA-2, AA-15, AA-29, AA-40, AA-43, AA-55, AA-69 and Lady Jane, and two *A. scherzerianum* cultivars, AS-1 and AS-2, were evaluated for their flower yield and floral characters under a 50per cent shade net condition. Among the *Anthurium andreanum* cultivars, AA-43 and Lady Jane recorded the highest number of flowers/plant per year (18.2), followed by AA-2 (11.2) and AA-29 (10.5) (Praneetha et al., 2002).

Premna (2003) observed the maximum number of spadices in the genotypes 'Acropolis White', 'OO x PR', 'PR x DT' and 'Tropical Red' (6) and minimum number in the variety 'Carre' (4.25).

The productivity and quality of six new cultivars: Carnival, Neon, Queen, Sante, Terra, and Vanilla were evaluated in soilless culture and under heated glasshouse conditions, Terra was the most productive one with 9.4 cut flowers per plant, followed by Neon and Vanilla, respectively, with 7.3 and 7.0 flowers per plant, the least productive was Carnival with 4.6 flowers (Talia et al, 2003).

Pravin (2004) revealed that one spadix each was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant were the same. The annual production of leaves or spadices was highest in Liver Red (7.00) which was on par with Orange Glory, Acropolis White and OG x DT (6.33). The lowest number of 4.67 was recorded by FR x MW (1) and NO x DT.

Srinivasa and Reddy, (2005) conducted an experiment to evaluate the performance of anthurium cultivars Honduras, Tinora, Senator, Tropical and Pasricha for cut flower production and out of these varieties Honduras recorded the maximum number of leaves (9.63) and spadices per plant (8.13).

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house. Mirage produced maximum number of leaves while Agnihotri, Mauritius and Wrinkled Orange produced higher number of leaves per month. Maximum number of flowers was obtained with Honey followed by Mauritius and Wrinkled Orange and these cultivars are suitable for flower production in Andamans.

2. 3.6 Days from Emergence to Maturity of Leaves

Mayadevi (2001) reported that the number of days required for the leaves from emergence to maturity ranged from 41.40 days in the variety 'Honeymoon Red' to 44.40 days in the variety 'Pink'.

Asish (2002) with 50 genotypes observed the average days for the emergence of leaves to its maturity as 27.56 with the range 15.33 days in 'OG x LR' to 41.00 days in 'DT x FR'. Premna (2003) noticed the least number of days for maturity by 'Carre' (26.25) and a maximum number of days for the genotype 'PR x DT' (40.25). The days from emergence to maturity of leaves ranged from 26.57 days in NO x DT to 35.67 days in Tropical Red (Pravin, 2004).

2. 3.7 Days from Emergence to Maturity of Inflorescence

Mayadevi (2001) observed that the days from emergence to maturity of inflorescence ranged from 44.60 days in 'Chilli Red' to 50.60 days in 'Honeymoon Red' among the parents while the range of this character in hybrids was from 41 days in 'HR x P' to 54 days in 'HR x KR'. Asish (2002) in his study observed that this character ranged from 16.67 days in 'NO x LR (1)' to 37.67 days in 'MO x KR (1)'. Premna (2003) recorded the lowest mean value for the variety 'Carre' (29.00 days).

Pravin (2004) in his study with 14 genotypes reported that the days from emergence to maturity of Inflorescence ranged from 31.00 days in KO x CR to 37.20 days in FR x MW(1).

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and they observed that the cultivars, Mauritius and Wrinkled Orange, took minimum time for flowering from flower initiation.

2. 3.8 Spathe Size

The spathe is the most attractive and valuable part of the flower. The size of spathe is a commercially important trait of anthurium flowers. Criley (1989) recorded that the spathe size could be derived as a measure of length x width (cm).

In a study conducted on the effect of different media and fertilizer levels on *Anthurium andreanum* cv. 'Ozaki Red', Higaki and Poole (1978)

noticed that flower size increased with age of the plant.

Based on the United States Department of Agriculture Standards, Singh (1987) proposed that anthurium flowers can be graded according to average length plus width of spadix, as miniature (under 8 cm), small (8-10 cm), medium (10-13 cm), large (13-15 cm) and extra large (15 cm).

In a study of five varieties of *Anthurium andreanum*, Bindu and Mercy (1994) observed the largest spathe size for 'Pink' (10.4 + 9.7 cm) and the smallest for 'Lady Jane' (6.5 + 3.5 cm). In a similar study Sindhu (1995) found that the varieties 'Pink' and 'Kalympong Red' produced super large flowers and the smallest were produced in the variety 'Miniature White'.

The variety 'Ruth Morat' syn. 'Lady Ruth' had spathes larger than those of variety 'Lady Jane', with a mean width and length of 5.01 and 7.68 cm respectively (Oglesby Plant Laboratory Inc., 1996). Henny (1999) recorded that the new variety *Anthurium andreanum* Red Hot had spathes six to seven cm long and four to five cm wide.

In a study with 100 different genotypes of anthurium, Maya Devi (2001) observed average spathe length was 10.80 cm with a range of 6.33 cm to 21.33 cm and width of spathe had an average of 7.76 cm. The width ranged from 4.27 cm to 13 cm.

Praneetha et al. (2002) evaluated eight *Anthurium andreanum* cultivars, and two *Anthurium scherzerianum* cultivars for their flower yield and floral characters under a 50per cent shade net condition. The maximum values for spathe length and width of 16.3 cm and 13.4 cm were observed in AA-2 and AA-29, respectively.

Talia et al, (2003) evaluated the productivity and quality of six new cultivars: Carnival, Neon, Queen, Santè, Terra, and Vanilla, in soilless culture and under heated glasshouse conditions. They reported that Queen showed a bigger spathe with a mean length of 23 cm and a mean width of 18 cm, whereas Santè exhibited the smallest spathe (10 cm for both parameters, on average).

Cristiano et al. (2007) conducted a comparative trial run on six Anthurium (*Anthurium andreanum*) cultivars for cut flower production (Cheers, Choco, Cognac, Pistacea, Premier and Simba) cultured by the soilless technique and reported that Premier showed a bigger spathe with a mean length of 23 cm and a mean width of 20 cm.

Shiva and Nair (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and observed that the spathe size ranged from 5.8 to 8.52 cm. The maximum spathe size was recorded in Mauritius followed by Honey.

2. 3.9 Anthocyanin Content

Abdussammed (1999) found that the anthocyanin content of Anthurium cv. 'Hawaiian Red' altered significantly under different levels of growth regulators and nutrient treatments. The highest value for anthocyanin content in ground and pot for nutrient were 85.07 mg g-1 and 93.9 mg g-1 respectively. While for growth regulators, the corresponding values were 67.88 mg g-1 and 84.18 mg g-1 respectively.

Mayadevi (2001) reported that mean total anthocyanin content ranged from 121.38 mg/g in Pink to 386.56 mg/g in Liver Red in the parents while the range of this character was from 146.03 mg/g (Honeymoon Red x Liver Red) to 330.95 mg/g (KR x CR) in the hybrids.

Asish (2002) in his study with 50 genotypes reported that the mean total anthocyanin content ranged from 26.81 mg/g in the genotype FR x KR to 710.79 mg/g in the genotype PR x LR (3). The total anthocyanin content on an average was 234.86 mg/g.

Premna (2003) in her study with 14 genoypes reported that the mean anthocyanin content ranged from 10.09 mg/g in Acropolis White to 259.18 mg/g in Honduras.

2. 3.10 Spadix Length

The candle (spadix) is the inflorescence proper, bearing small bisexual flowers embedded in slanting rows in an acropetal succession. The larger the candle, the more the number of flowers. Commercially, slender and short candles are preferred over thick candles.

Bindu (1992) reported the candle length of five varieties of *A. andreanum* which ranged from 4 cm to 9.5 cm. In ordinary varieties of 'Red', Pink' and 'White' the candle was long and fleshy but in highly bred hybrids and exotics, the candle was shorter and more slender according to Mercy and Dale (1994). The candle length of six varieties studied by Sindhu (1995) ranged from 6.6 cm to 12.1 cm.

Renu (2000) reported that the commercial varieties like 'Tropical Red', 'Nitta Orange', 'Mauritius Orange', 'Lady Jane Red', 'Pompon Red' and 'Midori Green' produced smaller candles. Mayadevi (2001) studied the candle length of 5 parents and 10 F_1 hybrids. Longest candle was recorded by 'Pink' (12.72 cm) and shortest in 'Liver Red' (7.18 cm.) among the parents. In the hybrids it ranged from 5.9 cm ('P x LR') to 10.38 cm ('HR x LR').

Asish (2002) reported that among the 50 genotypes studied by him 'FR x MW (2)' had the minimum candle length of 3.13 cm while 'FR x MW (1)' had the maximum candle length of 9.19 cm. Premna (2003) in her study with 14 genotypes observed the lowest value for candle length for the genotype 'FR x KR' (4.63 cm) which was on par with 'Carre' (4.88 cm) and 'LR x FR' (4.75 cm).

Praneetha et al (2002) evaluated eight *Anthurium andreanum* cultivars, and two *A. scherzerianum* cultivars for their flower yield and floral characters under a 50per cent shade net condition. They observed maximum spadix length by the cultivar AA-2 (13.0 cm).

Short and slender candle is a desirable feature for anthurium flowers. The genotypes MO x KR (1) (3.83 cm) and PR x FR (1) (4.97 cm) had short candles and PR x MO and LR x PR had longer candles (8.00 cm and 7.83 cm) which is not ideal (Pravin, 2004).

Srinivasa and Reddy (2005) conducted an experiment to evaluate the performance of anthurium cultivars Honduras, Tinora, Senator, Tropical and Pasricha for cut flower production. Among the cultivars Honduras recorded maximum spadix length and girth of 6.57 cm and 7.93 mm respectively.

Shiva and Nair, (2008 b) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and observed that the cultivar Colarado produced maximum spadix length.

2. 3.11 Inclination of Candle with the Spathe

Inclination of candle is an important factor as cut flower anthurium is considered. A downward curving candle is an extremely desirable character for commercial anthurium variety as this helps in packing a large number of inflorescence in a box during transportation.

Mercy and Dale (1994) reported that flower bearing candle in a good commercial variety was attached to the base of the spathe held at an angle slanting or curving at 25° to 40^0. According to them ideal anthurium spadix with a high market value must have shorter candle curving towards the tip of the spathe at an angle less than 45°.

In an investigation by Sindhu (1995) the maximum angle of 75^0 between the base of the candle to the plane of the spathe was observed in the var. 'Honeymoon Red', which is not desirable. The ideal Anthurium spadix with an angle less than 45^0 were found in varieties 'Chilli Red', 'Kalympong Orange', 'Kalympong Red'. Renu (2000) while studying anthurium varieties observed an ideal position of candles for 'Pompon Red', 'Chilli Red', 'Tropical Red', 'Mauritius Orange', 'Nitta Orange', 'Merengue White' and 'Midori Green'.

Mayadevi (2001) in her study with 5 parents and 10 F_1 hybrids observed that the inclination of the candle ranged from 21.00° in 'Kalympong Red' to 78.20° in 'Honeymoon Red' among the parents. The hybrids also showed significant difference for the character ranging from 20.80° ('HR x CR') to 89.60° ('HR x P'). Asish (2002) observed that inclination of the candle ranged

from 10.67° in 'PR x MO' to 89.33° in 'MO x KR (1)'. Premna (2003) reported the lowest angle for the genotype 'KR x LR' (21°) which was on par with 'PR x FR' (22.5°).

Pravin (2004) reported that among the 14 genotypes PR x MO had the minimum angle of 26.10° while MO x KR (1) had the maximum angle of 70.07°.

2. 3.12 Number of Flowers/spadix

The larger the candle the more number of flowers per candle. Though varieties like 'Honeymoon Red' and 'Pink' have large candles with flowers upto 400 or more. They are not preferred as these varieties are non-commercial. Ideal commercial varieties have smaller candles with less number of flowers.

Watson and Shirakawa (1967) observed that Anthurium 'flower' consisted of a modified leaf, the spathe and a flower bearing spadix with over 300 spirally attached minute flowers. Croat and Bunting (1978) reported that the flowers of anthurium were bisexual and was closely congested on a cylindrical spike and arranged in a series of spirals on the spadix.

Singh (1987) noticed that the anthurium flower is a combination of colourful modified leaf (spathe) and hundreds of small flowers on the pencil-like protrusion (spadix), the flowers are arranged in a series of spirals, both spadix and spathes are borne on a leafless stalk or peduncle. Bindu and Mercy (1994) were of the opinion that anthurium flower had a candle bearing about 50 -150 sessile flowers. Mercy and Dale in the same year reported that anthurium 'flower' was actually an inflorescence termed 'spadix' which is a racemose with a slender floral axis (candle) bearing 150-350 bisexual sessile flowers in an acropetal succession.

Sindhu (1995) observed that the average number of flowers produced were maximum in 'Pink' and 'Honeymoon Red' (325 flowers) and lowest in the variety 'Chilli Red' (175 flowers). Renu (2000) in her study found that number of flowers per candle varied from variety to variety, which ranged from 254 in 'Tropical Red' to 450 in 'Lady Jane Red'.

Mayadevi (2001) recorded that the number of flowers per candle ranged from 372 in 'Chilli Red' to 600 in 'Pink' among the parents. In the hybrids 'P x LR' had the minimum number of flowers per candle of about 400 while 'HR x DT' and 'P x KR' had the maximum number of flowers per candle of 600.

2. 3.13 Life of Spadix

Paull (1982) observed the visible changes accompanying the senescence of anthurium flowers as spathe-gloss loss, necrosis of spadix and greening of spathe and spadix. These changes were non reversible processes leading to the death of spadix.

Mercy and Dale (1994) reported that the life of unfertilized spadix was about 2 months while that of a fertilized inflorescence was about 4-7 months. Senescence was marked by yellowing of peduncle followed by withering of spathe and candle. Sindhu (1995) observed the life of unfertilized spadix which ranged from one and a half months in 'Kalympong Orange' to three and a half months in 'Honeymoon Red'. For fertilized spadices the period ranged from four and a half to eight months.

Valsalakumari et al. (1998) reported that *Anthurium andreanum* cv. 'Agnihotri' the longevity of spadix was maximum with 1000 ppm GA_3 which was on par with 1500 ppm GA_3. Abdussammed (1999) noticed that combined application of BA + GA_3 -250 ppm recorded the highest longevity of spadix.

Renu (2000) observed that among the 10 varieties studied, var. 'Nitta Orange' had a life span from the emergence of spathe to its senescence of 2.5 months while the variety 'Ceylon Red' had 3.7 months in case of unfertilized spadices. For fertilized spadices the life span was found to be higher ranging from about 3.8 to 7.5 months.

Mayadevi (2001) recorded the time span from emergence of a spadix to its senescence varied from 98 days in variety 'Chilli Red' to 120.40 days in 'Honeymoon Red' in case of unfertilized spadices.

Asish (2002) observed that the average days taken for opening of inflorescence to its death was 77.08. Premna (2003) noted the lowest mean for the life of the spadix in the variety 'Carre' (59.50 days) and the highest for PR x DT (101.50 days).

Shiva and Nair (2008) conducted a study to evaluate the performance of 14 anthurium cultivars under shade-net house and found that the shelf-life of flower on the plant was found to be longest in Wrinkled Orange followed by Honey.

2. 3.14 Days to Initiation of Female Phase

Croat (1980) stated that in anthurium species maturation of flowers was initiated generally from the basal portion of the spadix (candle) and development proceeds acropetally towards the apex.

Mercy and Dale (1994) reported that the flower of *Anthurium andreanum* is protogynous and the female reproductive structure or gynoecium reached receptivity about 4-7 days after the opening of the spathe. In 1995 Sindhu studied that the days to initiation of female phase occurred within a period up to 10 days, after opening of spathe, with the variety 'Honeymoon Red' showing the longest period for female phase initiation.

Renu (2000) in her study with 10 varieties reported that the mean number of days to initiation of female phase ranged from 3.60 days in 'Lady Jane Red' to 6.80 days in 'Mauritius Orange'. According to Mayadevi (2001) the number of days from the day the candle become visible to initiation of female phase vary from 4.40 days in 'Kalympong Red' to 6.80 days in 'Honeymoon Red' and 'Liver Red'. Among the hybrids studied it ranged from 3.60 to 6.20 days. She also reported the protogynous nature of species. Asish (2002) inferred that the average number of days required for the initiation of female phase was 6.1. Premna (2003) observed the mean number of days to initiation of female phase ranging from 2.75 in 'OO x KR' to 8.00 in 'PR x LR', 'PR x DT' and 'Tropical Red'.

The number of days required for visible initiation of female phase was observed to vary from 4.33 days in PR x MO to 9.27 days in PR x FR (1). Initiation of female phase was identified by the slight projection by stigmas and presence of viscous exudate on the candle (Pravin, 2004).

2. 3.15 Duration of Female Phase

Croat (1980) reported that the duration of pistillate phase was quite variable which ranged from only a few hours in *Anthurium ravenii* to 21-28 days in *A. luterynii* and *A. caperatum.* The female phase for the species *A. andreanum* varied from 3-12 days (Bindu, 1992).

Mercy and Dale (1994) observed the receptive female phase as a viscous colourless exudate secreted by receptive stigma which is sticky to touch. The receptive female phase lasted for three to seven days in different varieties.

Sindhu (1995) reported that female phase ranged from 5 to 25 days. According to Renu (2000) the duration of female phase varied from 6.4 days in 'Lady Jane Red' to 16.4 days in 'Mauritius Orange'. She also observed individual flower in which the duration lasted upto 21 days in 'Mauritius Orange'.

Mayadevi (2001) from her study observed that the duration of female phase ranged from 7.4 days in 'Pink' to 13.6 days in 'Kalympong Red' and in hybrids it ranged from 9.6 to 12.8 days.

Duration of female phase on an average lasted for about 6.1 days with a range 3.67 days in 'OG x KR' to 11.33 days in 'MW x FR (1)' in a study by Asish (2002). Premna (2003) reported that duration of female phase ranged from 5.50 to 9 days in 14 genotypes studied.

The duration of female phase in the 14 varieties of the present study varied from 5.50 days in OG x DT to 11 days in Acropolis White (Pravin, 2004).

2. 3.16 Duration of Interphase

The period between female and male phase was several days in most anthurium species, where as in a few of them the time lag was so short that it was not certain whether the species involved were homogamous or protogynous (Croat, 1980).

Bindu and Mercy (1994) observed that the stigmatic droplets dry up before any stamens emerge out. The interphase of five varieties studied by them ranged from four to seven days. They also found that during rainy seasons, the interphase is prolonged.

Mercy and Dale (1994) reported that the interphase was about one week. In a study by Sindhu (1995) the interphase in *Anthurium andreanum* ranged from four to ten days. Prolonged interphase with the suppression of male phase was observed from March to August in several varieties.

Renu (2000) observed that the interphase was marked by the drying up of stigmatic droplets. Observation from seven varieties showed that the interphase ranged from 4.8 to 10.2 days. The longest interphase was shown by 'Liver Red' and the shortest by 'Merengue White'.

Mayadevi (2001) from her study concluded that the interphase ranged from 7.80 days in 'Chilli Red' to 11.20 days in 'Pink'. Among the hybrids studied, 'HR x CR' and 'P x CR' recorded an interphase period of 9.39 and 12.60 days respectively. Asish (2002) observed that interphase ranged from 2.00 ('PR x KR') to 11.67 days ('MO x KR (2)'). According to Premna (2003) in a study with fourteen genotypes, the interphase ranged from 4.50 days ('Carre') to 9.25 days ('PR x DT').

The interphase between the female and male phase was marked by the drying up of stigmatic droplets. Observation from the fourteen varieties in the present study showed that the interphase may range from 2.33 to 6.83 days on an average (Pravin, 2004).

2. 3.17 Duration of Male Phase

Croat (1980) observed that the initiation of stamen emergence appeared to be equal from all parts of the spadix or initial maturation and staminal exertion appeared for many flowers in the basal fourth, basal third or basal half of the candle and further development proceeded in a systematic manner.

Bindu and Mercy (1994) recorded that the anther exertion started from the base and proceeded regularly towards the apex and the duration of male phase ranged from 3 to 7 days in the five *Anthurium andreanum* varieties studied by them.

Mercy and Dale (1994) reported that all the anthers on a candle emerged in about 4-8 days. According to Sindhu (1995) the male phase may range from 3-8 days depending on the variety. She also noticed irregular appearance of stamens on the candle.

Among the ten varieties studied by Renu (2000) she noticed that the average number of days of male phase ranged from 5.4 days in 'Mauritius Orange' to 10.4 days in 'Tropical Red'.

According to Mayadevi (2001) the days of anther emergence ranged from 5 days in the variety 'Chilli Red' to 7.20 days in variety 'Honeymoon Red'. Among crosses, a maximum of 9.60 days ('P x KR') to a minimum of 5.60 days ('HR x CR') was recorded. Asish (2002) observed a maximum duration of 12.67 days ('MW x PR') to a minimum of 4 days ('MW x DT'). Premna (2003) recorded maximum duration of 12 days for the variety 'Honduras' and lowest for 'Carre' (6.50 days).

Pravin (2004) reported that the average number of days for which the candles remained in male phase ranged from 5.33 days [PR x FR (1)] to 10.83 days (Acropolis White).

2. 3.18 Pollen Fertility

Appearance of the pollen alone at collection time is not always a good index of viability (Stanley and Linsken, 1974). So pollen fertility is tested either by using specific stains or by *in vitro* growth studies.

Lalithambika (1978) noticed in a study that the pollen sterility of different species of Anthurium varied from 63.0 per cent (*A. cordatum*) to 96.5 per cent (*A. veitchii*). She noticed a pollen sterility of 70-75 per cent for *A. andreanum*. Satyadas (1985) also reported that the pollen sterility varied from 67 per cent (*A. warocqueanum*) to 80 per cent (*A. ornatum*).

Bindu and Mercy (1994) noticed that the pollen fertility ranged from 20.4 per cent in 'Honeymoon Red' to 28.8 per cent in 'Pink'. They inferred that high pollen sterility may be due to high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, chromosome elimination through micronuclei etc. found in *Anthurium andreanum*.

Renu (2000) estimated the pollen fertility of ten varieties of anthurium and revealed that the variety 'Liver Red' had the highest pollen fertility of 42 per cent followed by 'Tropical Red' (29 per cent). 'Mauritius Orange' and 'Lady Jane Red' recorded the lowest fertility value of 14.0 and 13.7 per cent respectively.

Mayadevi (2001) from her study inferred that high pollen fertility was observed for the variety 'Liver Red' (45.90 per cent) followed by 'Pink' (28.40 per cent). Among the 50 genotypes studied by Asish (2002), pollen fertility was found to be 24.24 per cent on an average. Premna (2003) observed highest pollen fertility of 35.70 per cent for the variety 'Carre' followed by 'Honduras' 35.13 per cent.

Pollen fertility estimated using acetocarmine method indicated that most of the genotypes had low fertility values. 'PR x FR (1)' had the highest pollen fertility of 41.67 per cent followed by 'Liver Red' (40.67 per cent) (Pravin, 2004).

2. 3.19 Pollen Morphology (Size and Shape)

Bindu (1992) while studying pollen grains of five varieties observed that the size of pollen grains varied from 87.2 x 86.4 μ (Lady Jane) to 81.8 x 68.0 μ (Pink). All the varieties had more or less round pollen with a germ pore. Premna (2003) in her study with 14 genotypes noticed that the pollen size ranged from 22.64 μ in PR x FR to 28.48 μ in LR x PR. Among the fourteen genotypes studied by Pravin (2004), he noticed that the average pollen size ranged from 16.80μ in MO x KR (1) to 24.97μ in Liver Red.

2. 3.20 Colour of Young Leaf and Petiole

The colour of young tender leaves of *A. andreanum* varied from light green to deep reddish brown (Mercy and Dale, 1994). Sindhu (1995) observed that the petioles were slender and long and there were variations in the colour of both petiole and young leaves in all the varieties studied by her. The young tender leaves showed light green, green, greenish brown, light brown and brown colour. Colour of petiole and young leaf ranged from green to brownish green and brown as observed by Asish (2002). Premna (2003) noticed a range from brown to reddish brown to greenish brown to green. The colour of the petiole also varied from brown to reddish brown to greenish brown to green.

The colour of young leaf showed a range from brown to reddish brown to greenish brown to brownish green to green. The colour of petiole also varied from brown to light brown to reddish brown to greenish brown to green (Pravin, 2004).

2. 3.21 Spathe Colour

Spathe colour is an important character which gives a sense of pleasure to human beings. Spathe colour varies from pure white to deep maroon among the popular commercial varieties of anthurium. Pastal shades such as white, light pink, coral, light orange etc. are preferred in countries like China, Japan and Korea, while darker shades are preferred in middle east, USA, Singapore and Malaysia. The presence of 3-cyanidin glycoside and 1-pelergonidin

glycoside in the spathes of *Anthurium andreanum* was identified by Forsyth and Simmonds (1954), while the major spathe colours reported by them were red, orange, pink, green and white.

Birdsey (1956) described the spathe of native *Anthurium andreanum* from Columbia as orange scarlet or vermilon where as the commercial varieties showed a complete colour range from white to dark red. According to Lowry (1972), spathes of all the cultivars of anthurium contained both pelargonidin and cyanidin 3-rutinoside pigments.

Bailey (1976) identified *Anthurium andreanum* Lind "as one of the parents of a group of hybrids with large showy puckered spathes from black red to red, salmon pink and white".

Iwata et al. (1979) identified the pigments to be cyanidin 3-rhamnosyl glucoside and pelargonidin 3-rhamnosyl glucoside. Genetics of spathe colour revealed the presence of both the pigments in the red cultivars 'Ozaki', 'Kaumana','Kozahara','Kansako No.1' and 'Nakazqwa' and in the pink cultivar 'Marian seefurth'. The orange and coral coloured spathes contained only pelargonidin 3-rhamnosylglucoside. In white varieties both the pigments were absent.

Maurer (1979) while describing the techniques of cross pollination in *Anthurium scherzerianum* discussed the presence of recessive characters i.e., A = with anthocyanin and a = without anthocyanin, B = whole spathe coloured and b = spotted spathe. When the parents were Aa/Bb, the descendants were 9 red (AB), 3 red spots in white (Abb-) and 4 white (aaB- and aabb).

Iwata et al. (1985) stated that the spathe colour in anthurium was determined by the relative concentrations of anthocyanins, a predominance of cyanidin-3-rhamnosyl glucoside resulted in pink to red colour where as a predominance of pelargonidin-3-rhamnosyl glucoside resulted in coral to orange. Another pigment flavone which is present in large and variable amounts was characterised; but not demonstrated to have a modifying effect on cyanic shades.

Henny et al. (1988) inferred that the hybrid 'Southern Blush' produced through interspecific hybridization, had a medium pink spathe and with a slight lavender tint.

Kamemoto et al. (1988) after detailed analysis on the genetics of spathe colour in anthuriums concluded that two major genes, M and O were responsible for the five major colours: red, orange, pink, coral and white. The dosages of M and O genes affect the colours. The gene M was found to control the production of cyanidin-3-rutinoside while the gene O controlled pelargonidin-3-rutinoside. Red and pink resulted when both M and O genes were present with pink being the double heterozygote and orange and coral resulted when only O gene was present. White colour was produced in double recessive condition (mmoo). The recessive oo is epistatic to M and therefore white resulted when both were recessive (mmoo) or M was in combination with recessive oo (MMoo, Mmoo). Orange and White found to be true breeding. The incremental effects of M was greater than that of O and therefore the intensity of colours decreased from MMOO, MMOo, MmOO to MmOo. Orange is mmOO and coral is mmOo. Criley (1989) grouped the colours of the important cultivars and new introduction in Hawaii according to the Royal Horticultural Society Colour Chart.

Wannakrairoj and Kamemoto (1990) while studying inheritance of purple spathe in anthurium, proposed a scheme for the genetic control of purple spathe colour. A recessive allele 'p' modified the colour of anthocyanins controlled by M and O loci i.e., recessive epistasis. They observed that a spathe was purple when the genotype was M-O- pp. If the 'P' locus was dominant, M-O-PP was red, while mmOO-pp and mmO-PP are orange and coral. The 'P' allele has no effect on the white genotypes whether it is dominant or recessive.

Mercy and Dale (1994) were of the opinion that colour of spathe fades gradually as flowers gets older. After fertilization of candle, the spathe becomes gradually green and photosynthetic. They also reported that spathe colours varied from white to pink to coral to orange to brown to red to crimson to deep

maroon (liver red) and some varieties had spathes of two or three colours (obaki).

Sindhu (1995) observed that the dark and brightly coloured flowers, which are commercially important, were produced by the varieties 'Chilli Red' and 'Kalympong Red'.

Henny (1999) described that the new anthurium hybrid 'Red Hot' had spathes that were medium red at anthesis, which later changed to a lighter red prior to senescence.

Nirmala et al. (1999) reported that the relative concentrations of cyanidin and pelargonidin affects the spathe colour. They concluded that it is very difficult to relate the visible colour with anthocyanin in the spathe. Indian Institute of Horticultural Research grouped the genotypes into 4 groups (red, orange, coral and white) based on the presence of cyanidin and pelargonidin along with an unknown pigment. Renu (2000) grouped the spathe colour of 10 varieties into deep maroon to dark red, red, light orange, light orange to dark orange, light green and white.

Mayadevi (2001) inferred that anthocyanins contribute various colours to spathe from deep maroon to light pink. Red coloured varieties showed variation from dark red ('Chilli Red') to red ('Honeymoon Red'). The mean total anthocyanin content ranged from 121.38 mgg^{-1} in Pink to 386.56 mgg^{-1} in 'Liver Red' in the parents while the range of this character was from 146.03 mgg^{-1} ('HR x LR') to 330.95 mgg^{-1} ('KR x CR') in the hybrids. Based on the anthocyanin contents, the probable spathe colour of five parents and their F_1 hybrids have been worked out for the first time in anthurium by correlating the total average anthocyanin content of the spathe of each variety to the incremental effect of the two anthocyanin producing genes, M and O.

Asish (2002) in his study on 50 genotypes found that the spathe colour range was deep maroon, maroon, dark red, red, light red, dark orange, pink and white. The genotype 'OG x DT' had double colour spathe of red and green.

The spathe colour ranged from deep maroon to white in the 14 genotypes observed by Premna (2003).

Pravin (2004) in his study on 14 genotypes found that Liver red and LR x DT had deep maroon coloured spathe. Red coloured varieties showed variation from dark red (LR x PR, OG x DT and Tropical red) to red (KO x CR, PR x FR (1) and PR x KR). PR X MO and FRx MW (1) showed pink and light pink coloured spathe. OG and NO x DT had orange and dark orange coloured spathe.

Binodh and Devi (2006) studied relative concentrations of anthocyanin and its influence on spathe colour in 50 morphologically diverse and taxonomically complex genotypes of anthurium showing variations in spathe colour, shape, size and other commercially valuable morphological characters. They revealed that the mean total anthocyanin content ranged from 26.81 mg/g (pink spathe) to 710.79 mg/g (maroon spathe). The genes M and O were considered responsible for the expression of the different spathe colours (red, orange, pink and white). Genotypes having high anthocyanin content had maroon spathes, while those with low anthocyanin content had pink spathes. Cultivars with red spathes also had high anthocyanin content, and they may be exploited commercially to improve the export quality of cut flower anthurium. Shiva and Nair (2008 b) while studying 14 genotypes found that the spathe colour range was deep red, red and orange.

The inheritance of spathe color in anthurium (*Anthurium andreanum* Hort.) was studied in 77 crosses involving 59 parental genotypes by Winston and Pathmanathan (2008). The progeny segregated into "colored : white" did not fit the genetic model proposed by Kamemoto et al. (1988), but fit a duplicate recessive epistasis model involving genes O and R, in which either O or R or both in the recessive form would result in white-spathed progeny. The progeny segregation into red or orange group was in agreement with the Kamemoto et al. (1988) model and is determined by the status of the M gene. The dosage effect of particularly the R gene accounted for the differentiation of reds from pinks and oranges from corals.

2. 3.22 Spathe Texture

Blistered spathe texture is commercially preferred over a smooth spathe as the former is much more visually attractive.

According to Birdsey (1956), Linden described the spathe of *Anthurium andreanum* and its varying degrees of smoothness to blistering. Arndt (1991) reported that the spathe of *A. scherzerianum* variety 'Arabella' was broad with free lobes and a shallow sinus.Mercy and Dale (1994) suggested that the spathe in floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner deeply veined and blistered.

Sindhu (1995) observed that the variety 'Honeymoon Red' had smooth, thick and glossy spathe without prominent veins while 'Pink' and 'White' had smooth, thin and lightly veined spathes. Intermediate spathe texture and deep to shallow blisters were observed in varieties 'Kalympong Red', 'Kalympong Orange' and 'Chilli Red'.

Renu (2000) described the spathe texture in ten varieties of anthurium as thick smooth glossy, thin smooth glossy, thin shallowly blistered glossy, medium thick shallowly blistered glossy, thick medium blistered glossy and thick deeply blistered glossy.

Mayadevi (2001) while studying 5 parents and 10 F_1, hybrids in anthurium noticed thick, smooth and glossy spathe texture for 'Liver Red' and 'Honeymoon Red', medium thick smooth spathes for 'Pink' and thick deeply blistered glossy spathes for 'Kalympong Red' and 'Chilli Red' among the parents. Thick smooth and glossy spathes were observed for 'HR x P', 'HR x LR', 'HR x KR', 'P x CR', and 'KR x CR'. Medium thick blistered and glossy spathes for 'HR x CR' and 'P x LR'. 'P x KR' and 'LR x CR' showed thick medium blistered glossy spathes.

Asish (2002) noticed that spathe texture varied from thick blistered glossy, medium thick deeply blistered glossy, thick smooth glossy and medium thick smooth. Premna (2003) observed that spathe texture varied from thick

blistered glossy to medium thick deeply blistered glossy and thin smooth glossy.

Spathe texture showed wide variation among the 14 genotypes studied, from thick smooth and glossy to medium thick shallowly blistered glossy to thin slightly blistered glossy to thin blistered to thick medium blistered to medium thick deeply blistered glossy to medium thick blistered glossy spathes (Pravin, 2004).

2. 3. 23 Spadix Colour

In non-commercial and semi-commercial varieties like 'Honeymoon Red', 'Pink', 'White' etc., candles of single solid colours are usually seen. However most of the new hybrid varieties have double coloured candles.

Gajek and Schwarz (1980) identified the anthurium variety 'Iga Gold' with shiny red spathe and a white candle with yellow tip and variety 'Ellarina' with light salmon spathe and sulphur yellow spadix to be the best suited for green house cultivation.

Arndt (1991) reported that *A. scherzerianum* var. 'Arabella' had red spathe and candle. Mercy and Dale (1994) in their observations revealed that the candle had a single colour of red, pink or green in ordinary anthurium varieties and hybrids had candles with yellow, white, pink or red colour in two or more bands.

Sindhu (1995) reported that the six varieties studied had candles with either a single colour or two bands of colours. Henny (1999) reported that the new anthurium hybrid 'Red Hot' had candle, which is orange-red apically, blending to red basally. Renu (2000) in her study on ten varieties of *A. andreanum* observed that the candle had a single colour of pink, light pink, yellow, light yellow, green and light green. Mayadevi (2001) while studying the divergence of hundred genotypes observed candle colours of red, light red, pink, light pink, yellow, yellowish white, white and cream.

The candle colour varied from red to light red, reddish pink, pink, light pink, pinkish yellow, pinkish white, yellow, yellowish white and cream in fifty genotypes studied by Asish (2002). Premna (2003) observed that candle colour

varied from pink to cream, creamish yellow and yellowish white.

The candle colour varied from light yellow in LR x PR, FR x MW (1), KO x CR and PR x FR (1). It ranged from yellow in Tropical red, Acropolis White, Orange Glory, PR x MO, NO x DT and LR x DT. Liver Red and FR x MW (1) showed maroon coloured candle. Candle colour was pink in the genotype PR x KR and OG X DT (Pravin, 2004).

2. 3.24 Type of Inflorescence Axis

The nature of inflorescence axis is one of the most important factors that determines the appearance and hence the value of anthurium flowers, when marketed as cut flowers.

Mercy and Dale (1994) suggested that good anthurium hybrids should have short and straight inflorescence axis. Mayadevi (2001) reported that among the five parents and 10 F_1's studied, the axis nature varied from long, straight and very strong in all the parents and hybrids except for the parent variety 'Kalympong Red' in which it is long, thin and slightly curving.

Asish (2002) reported that long straight and strong inflorescence axis which is most desirable was exhibited by the genotypes 'NO x TR', 'MW x PR', 'TR x MW', 'PR x MW' and 'PR x LR (3)'. Premna (2003) observed long, straight and strong inflorescence axis in 'Acropolis White' and 'Tropical Red'. Among female parents inflorescence axis was long thin and curving for 'OO x KR' and 'PR x MW'.

Among the 14 genotypes studied straight and strong inflorescence axis which is more desirable was seen for Liver Red, Orange Glory, Acropolis White and Tropical Red (Pravin, 2004).

2. 3.25 Pollen Emergence Pattern

In *Anthurium andreanum* anthesis occurs on sunny days between 8 to 10 a.m. and on cloudy and rainy days anther dehiscence is delayed (Mercy and Dale, 1994). Sindhu (1995) observed that the interphase was prolonged with the suppression of male phase from March to August.

Renu (2000) revealed that anther dehiscence occurred in the early morning hours between 8 and 10 a.m. Pollen emergence pattern during the period of one year from August 1998 to July 1999 was analysed using Cochrans Q test for equality of proportions. The value of Q was found to be significant which showed that there was significant difference among the varieties with respect to pollen emergence. No pollen emergence was recorded for the varieties 'Pompon Red', 'Nitta Orange' and 'Midori Green' during that year. Also the emergence of pollen was found to follow a regular pattern in all the varieties except 'Merengue White'. In all the varieties, the pollen emergence was low in the months from March to June, during which the average maximum and minimum temperature were higher than the rest of the months. Pollen emergence was highest during October- November- December months.

2. 3.26 Stage of Harvest

The 'flowers' are harvested after the unfolding of the spathe is complete. The appearance of female phase on the spadix is also used as a criterion for harvesting the inflorescence.

According to Kamemoto (1962) 'flowers' are cut at the leaf axil when one third to three quarters of the bisexual flowers embedded in the fleshy spadix are open. Antoine (1994) opined that the 'flowers' are harvested in the morning with their long stalks and most blooms are harvested at about three quarters maturity because at this time it is believed that they have the longest shelf life as cut flower.

The spadix are cut for sale along with their long stalks when the spathes are fully opened and the candles show about one third to two third, female phase maturity, mostly around 7-10 days after spathe opening (Mercy and Dale, 1994).

Prasad et al. (1996) reported that anthurium 'flowers' are harvested when the spathe completely unfurls and the spadix is well develped. When one-third of the true flowers on the spadix mature, a change of colour can be observed that moves from base to tip of the spadix and at that stage, the flowers are harvested.

Salvi (1997) observed that in inflorescence having 1/3 rd flowers opened on spadix, the spathe blueing and glossy were late (20.0 and 22.3 days, respectively) and it also had the longest vase life (23.33 days). Singh (1998) had specified that anthurium flowers are harvested when three quarters of the stigmas along the spadix have become receptive.

2. 3.27 Pest and Disease Incidence

Insect pests and diseases are major factors that directly influence production, quality and marketability of the flowers. Control of pest and diseases constitutes a very important aspect in the day to day management of anthuriums.

Anthuriums are infected by anthracnose, leaf spot, root rot, powdery mildew, bacterial blight, mosaic and damping off. The two major diseases are bacterial blight and anthracnose. Blackening of the stem and decay of leaf axils are the symptoms of bacterial blight. Tiny circular black spots on leaf and spadix are the symptoms of anthracnose (KAU, 2007 and Sheela, 2008).

Though pests are not a problem in anthurium cultivation. The plants are infested by aphids, scales, thrips, spider mites, mole cricket and beetles are found to attack the plants and cause considerable damage. Among these aphids, thrips, scale insects and spider mites are the major pests. Snails and slugs also cause serious damage if left unattended (Bhatt and Deasi, 1989; Mercy and Dale, 1994; KAU, 2007 and Sheela, 2008).

Kuehnle et al. (1994) made attempts to transfer systemic resistance to bacterial pathogens from *A. antioquiense* to cultivated *A. andreanum* and got resistant F_1 hybrids. They concluded that production of horticulturally desirable varieties take many years because it is a perennial crop with a long juvenile stage (two to three years) and slow seed germination (six months).

During a survey on the diseases of anthuriums, a severe rotting *Xanthomonas* sp. incidence was observed in the anthurium plants in the anthurium house at the District Agricultural Farm, Mavelikara, Alleppey District, Kerala. The affected plants showed severe rotting of the leaf petioles.

Initially the symptoms appeared as pinhead sized water soaked areas, which spread very fast. Similar rotting symptoms were also observed at the base of the spadix also. The affected petioles and spadix came out with a slight pull. Yellowing and blackening of the leaf axils and spadix were also observed. About 100 per cent death of the plants was observed in the farm. Growth of a fungal pathogen *Colletotrichum gloeoporioides* (Penz) Penz Sacc was also observed. However, the incidence of a rotting complex involving these pathogens causing the death of the plants was reported for the first time in Kerala, India (Santha Kumari et al., 2001). The occurrence of a leaf and flower blight of anthurium was reported earlier by Naseema et al. (1997) and the incidence of a bacterial blight was also reported from Hawaii (Nishijima and Fujiyama, 1985).

2. 4 Variability Studies

Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement (Allard, 1960). The larger the variability, the better is the chance of identifying superior genotypes. Study of variability enables the breeder to determine the crop breeding strategies.

Genetically determined variation can be successfully selected only when the major part of the variability of the trait is genetic. The genetic parameters like coefficient of variation, heritability and genetic advance provide an exact picture of variability in a population.

Renu (2000) studied ten selected *Anthurium andreanum* varieties and reported that high PCV (phenotypic coefficient of variation) and GCV (genotypic coefficient of variation) for the characters plant height, position of candle, days to initiation of female phase, number of days in female phase and spathe size.

In a study with 100 different genotypes of anthurium, Maya Devi (2001) observed significant differences among the genotypes for plant height, spathe length, spathe width, number of suckers per plant, length of leaf blade, width of

leaf blade, candle length, inclination of candle, number of spadices/ plant/ year and leaf area. Maximum variability both at phenotypic (48.64 per cent) and genotypic (41.84 per cent) levels was observed for number of suckers per plant followed by leaf area, inclination of candle, width of leaf blade and the minimum was recorded for number of spadices/ plant/ year (PCV 15.42 per cent and GCV 10.46 per cent).

Asish et al. (2003) studied 50 genotypes of anthurium and reported that maximum variability both at phenotypic (PCV) and genotypic levels (GCV) for total anthocyanin content (PCV 57.91% and GCV 57.83%), followed by pollen fertility (PCV 42.42% and GCV 42.22%) and inclination of candle to spathe (PCV 40.97% and GCV 40.86%). Days of interphase and leaf area also registered high values at both phenotypic and genotypic levels. Minimum variability was recorded by days from emergence to inflorescence maturity (13.70% for PCV and 13.58% for GCV). High PCV combined with high GCV were obtained for total anthocyanin content, pollen fertility, inclination of candle to spathe, days of interphase and leaf area. Total anthocyanin content recorded the highest GCV and PCV. Lower GCV and PCV values were estimated for days from emergence to inflorescence maturity, number of spadices per plant per year and internode length, indicating a low magnitude of variability. Suckering ability, number of spadices per plant per year, plant height and candle length showed maximum differences between GCV and PCV.

Variability studies revealed that high PCV along with high GCV were present for number of suckers per plant, inclination of candle and anthocyanin content (Premna, 2003).

Variability studies indicated high phenotypic and genotypic coefficients of variation for the characters number of suckers per plant, pollen fertility and duration of male phase. The minimum variability was recorded by the character days from emergency to maturity of inflorescence (Pravin, 2004).

In a variability study conducted by Shiva and Nair (2008c) significant differences were observed among the 14 anthurium (*Anthurium andreanum*)

genotypes for 15 quantitative characters. Estimates of phenotypic and genotypic coefficients of variations were high for number of suckers per plant, number of leaves per plant and number of flowers per plant.

2.5 Heritability and Genetic Advance

Genotypic coefficient along with heritability estimates gives better idea about the amount of genetic advance in the next generation (Burton, 1952). Estimation of GCV alone is not enough to determine the amount of heritable variation. Heritable variation can be found out with greater degree of accuracy, if the heritability is coupled with genetic advance (Johnson et al., 1955).

Renu (2000) studied ten selected *Anthurium andreanum* varieties and reported that high heritability coupled with high genetic advance values for plant height, spathe size, spathe- candle ratio, position of candle, number of flowers per candle and days to initiation of female phase.

Maya Devi (2001) in a study with 100 genotypes of anthurium found high heritability coupled with high genetic advance values for plant height, spathe length, spathe width, number of suckers per plant, length of leaf blade, width of leaf blade, candle length, inclination of candle and leaf area.

Asish (2002) reported high heritability coupled with high genetic advance values for plant height, internode length, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, candle length, inclination of candle to spathe, number of flowers per candle, life of spadix, days to initiation of female phase, days to inter phase, durtaion of male phase, pollen fertility and anthocyanin content.

High heritability was recorded for anthocyanin content (99.73%), followed by inclination of candle to spathe (99.45%), life of spadix (99.43%) and pollen fertility (99.05%). Number of spadices per plant per year recorded a low heritability of 39.34%. Maximum genetic advance was obtained for anthocyanin content (118.98%), followed by pollen fertility (86.55%) (Asish et al., 2003).

The characters leaf area, anthocyanin content, inclination of candle, life of spadix and pollen fertility showed high heritability along with high genetic advance (Premna, 2003).

The characters with high heritability coupled with high genetic advance values were found for characters plant height, internode length, number of suckers per plant, leaf size, candle length, inclination of candle with spathe, life of spadix, days to initiation of female phase, duration of male phase, pollen fertility and pollen size (Pravin, 2004).

The characters, number of flowers per plant, time taken for flowering, peduncle length, leaf area, plant spread, shelf life of flower on plant and plant height exhibited high heritability along with high genetic advance which indicated that there was additive gene action in expression of these traits and thereby further improvement could be brought by selection (Shiva and Nair, 2008c).

2.6 Correlation Studies

Renu (2000) studied ten selected *Anthurium andreanum* varieties and reported that number of flowers per candle showed maximum positive genotypic correlation with candle length followed by plant height and number of leaves or spadices. Phenotypic correlation was significantly positive with number of leaves/spadices per year followed by candle length, where as it was negative with spathe- candle ratio. Plant height positively correlated at genotypic level with number of leaves/ spadices per year. Spathe size and candle length were positively correlated at phenotypic, genotypic and environmental levels. Candle length showed high positive genotypic correlation with position of the candle and number of flowers per candle. Life of spadix was found to have high genotypic correlation with candle length, spathe size, number of leaves or spadices per year, plant height, number of days in female phase and spathe-candle ratio.

Maya Devi (2001) reported that candle length and leaf area exhibited significant positive genotypic correlations with plant height. Spathe length and spathe width had significant positive genotypic correlation with candle length and leaf area both at genotypic and phenotypic level.

Asish (2002) reported positive correlation of plant height with internodal length, leaf area and days from emergence to maturity of inflorescence. Candle length showed positive correlation with leaf area and life of spadix. Life of spadix was found to have positive correlation with leaf area and candle length while it showed negative correlation with days from emergence to maturity of leaves.

Premna (2003) reported positive correlation of plant height with internodal length, leaf area, number of leaves per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant, candle length, inclination of candle, life of spadix, days to initiation of female phase, duration of female phase, duration of inter phase and duration of male phase. Candle length showed positive correlation with position of candle at both levels. Life of spadix was found to have positive phenotypic and genotypic correlation with internodal length, leaf area, number of leaves per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant, candle length, inclination of candle, days to initiation of female phase, duration of female phase, duration of inter phase, duration of male phase and pollen fertility.

Binodh et al. (2004) reported that number of flowers per candle had positive significant correlation with many interrelated characters, i.e. internode length, leaf area, days from emergence to maturity of inflorescence, candle length, life of spadix and duration of female phase.

Plant height was found to have highly significant positive phenotypic correlation with number of suckers per plant, leaf size, internode length, number

of spadices per plant and pollen fertility and showed negative significant correlation with days to initiation of female phase. Plant height also showed positive genotypic correlation with most of the characters. Candle length showed negative genotypic correlation with days to initiation of female phase, inclination of candle, pollen fertility and pollen size (Pravin, 2004).

Shiva and Nair (2008a) reported that the estimate of genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficient both for vegetative and floral characters. Among the vegetative characters, the number of suckers per plant was found to be positively and significantly associated with number of leaves per plant, leaf fresh weight and plant spread. Among the floral characters, spathe size, shelf-life of flower on plant, peduncle length and number of coils per spadix had a strong and positive association with number of flowers per plant.

In anthurium, Shiva and Nair (2008c) reported that the number of suckers per plant was positively and significantly correlated with plant height, plant spread, leaf fresh weight, number of leaves per plant, leaf area and leaf dry weight. A significant and positive association of flowers per plant was obtained with spathe size, peduncle length and shelf life of flower indicating that with the increase in these associated characters, the sucker and flower production could be improved. In general, both the sucker production and flower production are negatively correlated with each other.

2.7 Path Analysis

Path coefficient is a standardised partial regression coefficient which measures the direct influence of one variable (cause) upon another (effect) and permits the separation of correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959). The information obtained from path analysis helps in indirect selection for genetic improvement of yield.

Binodh et al. (2004) reported that leaf area and duration of female phase had positive direct effect on number of flowers per candle. Shiva and Nair

(2008a) reported that leaf fresh weight, number of leaves per plant and leaf area had a high positive direct effect on sucker yield where as time taken for flowering had high positive direct effect on flower yield per plant.

2.8 Genetic Divergence

The concept of the measure of divergence between populations was first introduced and further developed on the theoretical side by Mahalanobis (1925). A measure of group distance based on multiple characters was given by Mahalanobis (1928). In 1936, Mahalanobis suggested the generalized distance which has become the standard measure of distance between two populations when all the observed characters are quantitative.

Knowledge of genetic divergence among the different genotypes is very essential in selection of parents for hybridization programme. According to Singh and Gupta (1968), the more divergent the parents with a reasonable range, the more would be the chance of improving a character in question through hybridization programme.

D^2 analysis has also been effectively employed for identification of traits contributing to genetic divergence and grouping of cultivars in vegetatively propagated crops like banana (Valsalakumari et al., 1985; Mercy and George, 1987, 1988) and sugarcane (Punia et al., 1983; Santhi, 1989).

Maya Devi (2001) grouped 100 genotypes of anthurium into seventeen clusters based on genetic divergence using Mahalanobis D^2 statistics. The cluster 3 had the highest number of genotypes (15) followed by cluster 2 (13) and cluster 1(12) while three hybrid genotypes Honeymoon Red x Lady Jane (1), Ordinary Orange x Kalympong Red (3) and Ordinary Orange x Kalympong Red (8) remained as divergent genotypes that cannot be accommodated in any of the clusters and each remained as a separate cluster. Leaf area and suckering ability were found to be the two characters that contributed maximum for the divergence of the genotypes.

2.9 Selection Index

The economic worth of plant depends upon several characters. So while selecting a desirable plant from a segregating population the plant breeder has to give due consideration to characters of economic importance. Selection index is one such method of selecting plants for crop improvement based on several characters of importance. This method was proposed by Smith (1947) using discriminate function (Fisher, 1936).

Binodh and Devi (2005) worked out the selection indices for 50 anthurium (*Anthurium andreanum*) genotypes on the basis of 17 characters viz., plant height, internode length, suckering ability, leaf area, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, number of spadices per plant per year, candle length, inclination degree of candle to spathe, number of flowers per candle, life of spadix, days to initiation of the female phase, duration of the female phase, days of interphase, duration of the male phase, pollen fertility and anthocyanin content. Based on the analysis the highest selection index values were observed in genotype LR x DT followed by FR x MW.

In a study with 14 anthurium genotypes Shiva and Nair (2008a) reported that selection index comprising the characters like number of leaves per plant, leaf fresh weight and plant spread on sucker yield and the characters like spathe size, shelf-life of flower on plant, peduncle length and number of coils per spadix on flower yield can be considered highly dependable and reliable characters for selection to improve yield in anthurium.

2.10 Compatibility Studies

According to Kamemoto and Nakasone (1955), hybridization and selection were the most common methods for improving anthuriums. Productivity, flower colour, shape and texture, short internodes and suckering ability are different characters to be considered in selection. Controlled hybridisation indicated that neither white nor red flower colour was dominant

and pink was an intermediate heterozygous condition.

A general mode of spathe colour inheritance in *Anthurium andreanum* was suggested by several investigators (Kamemoto and Nakasone, 1955, 1963, Kamemoto et al., 1969; Sheffer and Kamemoto, 1977) based on intraspecific and interspecific hybridization.

Selection has been widely used as a method to develop suitable cultivars in the major anthurium producing countries. Of 113 clones evaluated by Kamemoto and Nakasone (1963), 13 were recommended for commercial cut flower production. Two cultivars i.e., 'Uniwai' (an exceptionally high yielding 'White') and 'Marian Seefurth' with a rose coloured spathe were evolved by clonal selection. They also postulated that the inheritance of spathe colour was under the control of multiple alleles and modifying genes. The presence of both the orange and magenta pigments in the Pink cultivar, 'Marian Seefurth', which arose from nine crosses between a white clone and a pink clone, substantiates the hypothesis that separate genes designated as M and O are responsible for the production of magenta and orange pigments respectively.

Kamemoto et al. (1969) described two seedling selections 'Anuenue' and 'Chameleon' for cut flower production and a compact clone 'Red Elf' suitable for growing as a pot plant. Sheffer and Kamemoto (1977) noticed good cross compatibility among *Anthurium andreanum, Anthurium nymphaefolium* and *Anthurium pinchinchae.* Using this they developed some cultivars, all of which successfully followed.

Sheffer and Kamemoto (1978) evaluated the interspecific cross compatibilities among 56 species of *Anthurium* and they concluded that interspecific hybrids with *Anthurium andreanum* and *Anthurium scherzerianum* were not readily obtainable. But they got hybrids of *Anthurium andreanum* with six other closely related species.

Kaneko and Kamemoto (1978) revealed that the chromosome numbers 2n=30 for *A. andreanum* Linden. 'Kaumana' and 2n=30+2B for 'Uniwai'.

Meiotic configurations in pollen mother cells were similar for both, with the exception of 2B chromosomes in the latter. They concluded that meiotic irregularities suggested a hybrid origin for cultivated anthuriums.

A new species hybrid, with a greyish-orange spathe was developed from the cross *Anthurium scherzerianum* x *Anthurium wendlingerii* by Sheffer and Kamemoto (1978), characteristics such as the length and coil of the spadix and the length and position of the leaf blade were intermediate between the highly contrasting characteristics of the parental species. Fertility in the hybrid was good indicating the relatively close taxonomic relationship of the two species.

Kaneko and Kamemoto (1979) analysed the chromosome number of *Anthurium* sp. as 2n=30+3B. They informed that the appearance of offspring with 2,3 and 4B chromosome, on self pollination indicated the transmission of B chromosomes through both pollen and egg. Maurer (1979) described the techniques of cross pollinating *Anthurium scherzerianum* and discussed the presence of recessive characters like lack of anthocyanin, spotted spathe etc.

Leeuwen (1984) in an evaluation trial identified the anthurium cultivars 'Avo-nette', 'Avo-tineko', 'Favoriet', 'Germa', 'Avo-claudia', 'Avo-ingrid', 'Nova-Aurora', 'Avo-Jose', Jamaica', 'Hoenette', 'Sarina' and 'Avo-Anueke' to be the best.

Zimmer (1986) while reviewing the problems in the development of anthurium cultivars observed that in *Anthurium scherzerianum* first inflorescence appeared 12-15 months after sowing but began flowering regularly only after 18-24 months. The spadix seldom had full fruit set. Tissue culture from selected genotypes took, 4-5 months to become plantlets. He added that the selection of a promising genotype took 10-12 years.

Henny et al. (1988) obtained 'Southern Blush', a hybrid for foliage producers through interspecific hybridization of a large pink-flowered *Anthurium andreanum* and *Anthurium amnicola* (a dwarf species collected from Costa Rica, which is very floriferous but bears small lavender spathes, nearly

more than 2 cm long) 'Southern Blush' was intermediate in size between its parents, spathes were about 7.0 cm long and 5.0 cm wide and were medium pink with a slight lavender tint.

Marutani et al. (1993) conducted detailed cytological analysis of *Anthurium andreanum,* its related taxa and their hybrids. They concluded that regular bivalent formation at prometaphase I of meiosis in pollen mother cells of species hybrids suggested close genomic relationships among parental taxa. On the other hand, reduction in pollen fertility estimated by the pollen stainability in those hybrids suggested genetic divergence of the species.

Mercy and Dale (1994) opined that hybridization between selected varieties with good combining ability could produce novel and valuable anthurium hybrids. They also added that a commercial variety should have small to medium sized leaves, extensive root system, short internodes, strong and straight inflorescence and short, thin and downward curving candles.

Sindhu (1995) recorded that a large number of combinations were incompatible. The maximum percentage of fruits (52.3 per cent) was harvested from the cross 'P x HR'. Among the 24 combinations obtained 'HR x P' and 'P x HR' were found to show the highest compatibility. The duration of fruit maturity ranged from 4.5 to 8.0 months.

Anthura (1997) submitted for registration, anthurium variety 'Champion', derived from *Anthurium andreanum* hybrids. This variety had small leaves and flowers cupped white spathe held above the canopy and red spadix. Henny (1999) found that the new interspecific anthurium hybrid Red Hot is highly suitable for pot planting because of its compact growth, freely branching growth habit and production of numerous showy red spathes.

Cross compatibility studies were done by Renu (2000) in 10 varieties based on the percentage of candles bearing fruits, fruit set and seed germination. The percentages of fruit bearing candles were highest for 'Nitta Orange' (51.43) and lowest for 'Mauritius Orange' (9.51). The percentage of fruit set was below

50 for all the crosses except for 'Pompon Red' and 'Liver Red'. The cross involving variety 'Pompon Red' as female had the highest percentage of fruit set. Seed germination was highest (87.5 per cent) for the cross 'Dragons Tongue' x 'Merengue White'. Scoring of the compatibility reactions based on fruiting candles, fruit set and seed germination, on a scale ranging from 0 to 9, showed the highest compatibility score for PR x LR and CR x MW crosses. The best female parents were found to be varieties 'Nitta Orange', 'Liver Red' and 'Pompon Red'. Varieties 'Ceylon Red', 'Merengue White' and 'Liver Red' performed well as pollen parents. The varieties 'Ceylon Red' and 'Liver Red' performed well both as female and male parents.

Premna (2003) after scoring the different genotypes and crosses obtained scale from zero to nine. The cross with the highest compatibility score of nine was for '(OO x KR)' x C and the best female parents observed were 'OO x PR' and 'PR x LR'.

Pravin (2004) after scoring the different genotypes and crosses obtained on a scale from zero to nine, the crosses with highest compatibility score of eight were for the crosses ('PR x KR') x AW, ('LR x PR') x OG, ('PR x MO') x LR and ('PR x MO') x AW. The performance of the variety as female parent was found to be different from its performance as male parent. Among the ten female parents 'PR x MO', 'LR x PR' and 'PR x KR' performed as the best female parents and among the four male parents 'Liver Red' performed as the best pollen parent.

2.10.1 Percentage of Spadix Bearing Berries

Sheffer and Kamemoto in 1976a did 1592 pollinations which include 20 selfs, 19 intraspecific cross combinations, 315 intra group interspecific cross combinations (including reciprocals) and 29 different intra group cross combinations (including reciprocals). The species were divided into six distinct morphological groups on the basis of important Englerian characters of the number of ovules per locule, colour and shape of the berry, shape of inflorescence, shape and texture of the leaf. The species were divided into six

distinct morphological groups. Group I and II were separated on the basis of the number of ovules per locule. Group III and IV were Engler's sections *Pachynerium* and *Schizoplacium* respectively. The remaining species were included under groups V and VI and were organized into two groups on the basis of leaf texture, berry shape and colour. Intra and inter group pollinations were done, fruits harvested and germinating seeds obtained.

Self-pollination resulted in 81 per cent fruiting spadices. Intraspecific and interspecific cross combination resulted in 65.4 per cent and 28.1 per cent fruiting spadices respectively. Group I, III and V gave higher percentage of fruiting spadices and flowering hybrids than group I, IV and VI. The presence of B-chromosomes also effected the viability (Bhattaglia, 1964, Sheffer and Kamemoto, 1976a).

All the six varieties of *Anthurium andreanum* studied by Sindhu (1995) viz., 'Honeymoon Red', 'Chilli Red', 'Kalympong Orange', 'Kalympong Red', 'Pink', and 'White', showed good percentage of candle bearing fruits. It was maximum (93 per cent) for the variety 'White' and lowest (50 per cent) for the variety 'Kalympong Red'. On the results of intervarietal hybridization using ten varieties of *Anthurium andreanum*, Renu (2000) observed that the percentage of fruit bearing candles was highest (51.93) for 'Nitta Orange' and lowest (9.51) for 'Mauritius Orange'. The only two selfings that produced fruiting candles were for varieties 'Liver Red' and 'Dragon's Tongue'. Among the cross combinations attempted the percentage of fruiting candles was 100 per cent for nine crosses in a study on 14 genotypes studied by Premna (2003). Among the 12 successful crosses percentage of candles bearing fruits was 100 per cent for six crosses (Pravin, 2004).

2.10.2 Number of Berries/Spadix

Zimmer (1986) identified the absence of full fruit set in a spadix as a major problem in the development of anthurium cultivars. He added that the period of 5-12 months taken for fruit ripening also was an impediment.

Mercy and Dale (1994) observed that in a well-fertilized candle about 100 to 200 or more berries had developed. A candle with developing fruits should be visually identified from the second month of fertilization as it become swollen and fleshy with developing fruits embedded in it. In about eight weeks, tip of the berries started projecting out like small pin heads.

Among the six varieties studied by Sindhu (1995) the maximum average number of fruits was produced in the 'Pink' variety followed by 'Honeymoon Red'. The maximum number of fruits were harvested from the cross 'Pink' x 'Honeymoon Red' (170) and the lowest number from 'Kalympong Red' x 'Kalympong Red (2)'.

Among the ten varieties studied by Renu (2000) the number of fruits per candle ranged from 5 to 183. The variety 'Pompon Red' had the highest average number of fruits per candle and it was lowest for 'Lady Jane'.

Premna (2003) observed highest fruit set in the cross ('OO x KR') x C (120) and no berries were obtained for 'PR x FR', 'DR x MW', 'PR x DT' and 'LR x FR'.

Among the 12 successful crosses studied by Pravin (2004) percentage of candles bearing fruits was 100 per cent for six crosses. Maximum number of 113 fruits was obtained for the cross ('LR x PR') x OG followed by ['FR x MW (1)'] x LR with 88 fruits. The average number of fruits per candles was highest for 'LR x PR' and lowest for 'PR x FR (1)'.

2.10.3 Percentage of Berry Set /Spadix

Based on cross compatibility studies using six varieties, Sindhu (1995) recorded that the maximum percentage of fruit set for the cross 'P x HR' (52.3 per cent) followed by 'HR x P' (44.3 per cent). The lowest percentage fruit set was observed in the cross 'KR x KR' (0.4 per cent).

Renu (2000) reported that the percentage of fruit set was below 50 per cent for all the crosses involving two varieties of *Anthurium andreanum* except 'Pompon Red' x 'Liver Red'. The cross involving 'Pompon Red' as female parent had the highest percentage of fruit set.

Premna (2003) observed highest fruit set for the cross ('OO x KR') x C (34.29 per cent). Among the ten female parents, the highest average percentage fruit set was observed for 'OO x KR' (29.03 per cent).

Pravin (2004) reported that the percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for 'PR x FR (1)' and 'LR x PR' respectively.

2.10.4 Number of Seeds/Berry

Zimmer (1986) while evaluating the development of anthurium cultivars observed that the berries contained two to three seeds and for ripening it took 5-12 months.

Geier (1989) reported that the time required for seed maturity was about 6-7 months for *Anthurium andreanum* and 10-12 months for *Anthurium scherzerianum.*

According to Mercy and Dale (1994) in the commercial varieties of *Anthurium andreanum*, each berry contained one or two seeds and the seeds matured in about 4-7.5 months. Seeds remain enclosed within the thin fruit wall in a gelatinous pulp and if not harvested, remain attached to the candle for a few days more before they dried up and fell off the candle.

In the compatibility study using six varieties by Sindhu (1995), the percentage of single seeds produced were more than the double seeds except in the cross 'Kalympong Red' x 'Honeymoon Red', where the percentage of double seeds was 63 per cent. The percentage of single seeds ranged from 37 per cent to 100 per cent.

Renu (2000) in study on ten varieties observed that the percentage of single seeded berries ranged from 34.30 to 100 percent and that of double seeded from 0 to 62.50. Premna (2003) observed that the percentage of single seeds were more than the double seeds in most of the crosses.

Pravin (2004) reported that most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross between 'LR x PR' and 'Orange Glory'

2.10.5 Seed Size

Sindhu (1995) recorded that the berries were usually single seeded and sometimes double seeded. When two seeds were seen in a berry usually one of them was smaller. 'Pink' and 'Honeymoon Red' varieties produced larger sized seeds and the Kalympong varieties produced comparatively smaller sized seeds.

Renu (2000) reported that largest seeds in double seeded berries was for the crosses 'PR x LR', 'PR x DT' and 'MW x LR' and among the single seeded crosses, 'TR x MW' had the largest size.

Premna (2003) observed the maximum average length and width in single seeded berries for the cross 'PR x LR' x Tropical (5mm x 4mm) and for double seeded it was (4.25mm x2.50mm) for the crosses 'CR x LR' x 'Honduras' and 'W x LJ x 'Acropolis White'.

2.10.6 Seed Germination (%)

Zimmer and Bahnemann (1982) found that seeds of *Anthurium scherzerianum* from different sources varied in their ability to germinate at low, suboptimal temperatures. Optimum germination temperature was recorded to be 20 – 25 ^{0}C, but some seeds germinated well at 10 or 15 ^{0}C.

Szendel et al. (1992) germinated the seeds of *Anthurium andreanum* harvested at three maturity stages and those of *Anthurium scherzecianum* at one maturity stage (light orange) on three substrates, at pH ranging from 4 to 8 in light or darkness at 18, 24 or 28°C. In *Anthurium andreanum* the best germination was obtained on a high peat substrate, at pH 4-5 in light at 28° C using seeds harvested at an early maturity stage.

Criley (1989) reported that, in anthurium the pulp was removed from ripe berries in water and the seeds were sown immediately on the surface of a damp

medium and placed under 80 per cent shade in conditions of high humidity. The germination proceeded within 14 days.

Mercy and Dale (1994) reported that, the hybrid seeds from crosses between ordinary hardy varieties of *Anthurium andreanum* had above 90 per cent germination and their seedlings showed high survival fitness and vigour.

Sindhu (1995) observed that the maximum average seed germination was observed in combinations with the variety 'White' as the female parent (63.4 per cent) and the lowest germination in the variety 'Kalympong Orange'. Highest germination percentage among the crosses was recorded for the cross 'Honeymoon Red' x 'Chilli Red' (78.0 per cent).

Renu (2000) recorded that the seed germination was highest (87.5 per cent) in 'Dragon's Tongue Red' x 'Merengue White'. Seed germination percentage varied from 69 per cent in 'Tropical Red' to 2.3 per cent in 'Midori Green' among the varieties.

Premna (2003) recorded highest average germination percentage for the cross 'W x LJ' x 'Honduras' (88.90 per cent) and lowest for PR x LR x 'Acropolis White' (49 per cent).

Pravin (2004) recorded that the number of days for germination varied from 4 to 9 days in various crosses. The range of 4 to 8 was observed in two crosses ['FR x MW (1)'] x LR and ['PR x FR (1)'] x LR. The seeds obtained from most of the crosses showed a germination percentage of more than 50 per cent. It was lowest in 'OG x DT' (63.86 per cent) and highest in 'PR x FR (1)' (80.86 per cent).

2.10.7 Seedling viability

Renu (2000) observed that the highest average seedling survival was recorded for Mauritius Orange. None of the seedlings involving Midori Green survived. Lady Jane also recorded a low seedling survival of 32.4 per cent. Out of the 34 combinations that germinated successfully, seedlings belonging to three crosses did not survive beyond four months.

Premna (2003) recorded that seedlings of 12 out of 13 crosses that germinated survived for more than four months. The highest average survival was recorded by FR x KR and lowest was recorded for the genotype KR x LR.

Pravin (2004) observed seedlings of 9 out of 12 crosses that germinated survived for more than four months. The highest average survival was recorded by 'OG x DT' (with only one cross) and lowest was recorded for the genotype 'PR x MO'.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken to identify suitable parents with commercial qualities and to determine the cross compatibility among the selected parents. The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, during 2006- 2009. The green house study conducted in two experiments *i.e.,*

Experiment I: a. Evaluation of genotypes to identify suitable parents for hybridization,

b. Hybridization and

Experiment II: Cross compatibility analysis

Materials and methods of both the experiments were presented below under separate subheads.

3.1 Experiment No. I:

3.1.1 MATERIALS

The following 29 varieties and 11 different hybrid genotypes of anthurium showing variations in spathe colour, shape and size and other commercially valuable morphological characters, generated through hybridization in an NARP (SR) Project available in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani and from approved commercial growers were utilised for the study (Plate.1). Fifteen parent varieties will be identified based on morphological and floral characters for hybridization.

1. Acropolis white (AW)
2. Carrie (C)
3. Tropical Red x Merengue White (TR x MW)
4. Pompon Red x Dragon's Tongue [PR x DT(1)]
5. Dragon's Tongue (DT)
6. Pompon Red x Orange Glory (PR x OG)
7. Kalympong Red x Liver Red (KR x LR)
8. Liver Red (LR)

9. Fla Red (FR)
10. Orange Glory x Dragon's Tongue (OG x DT)
11. Pompon Red x Dragon's Tongue [PR x DT (2)]
12. Pompon Red x Fla Red (PR x FR)
13. Pompon Red x Liver Red (PR x LR)
14. Nitta Orange x Dragon's Tongue (NO x DT)
15. Orange Glory (OG)
16. White x Lady Jane (W x LJ)
17. Pompon Red (PR)
18. Kalimpong Orange(KO)
19. Lady Jane (LJ)
20. Liver Red x Pompon Red (LR x PR)
21. Agnihotri (AH)
22. Lucia pink (LP)
23. Nitta Orange (NO)
24. Gold Spark (GS)
25. Chekas
26. Vesuvious Red (VR)
27. Boroque
28. Arun Gold (AG)
29. Geisha white (GW)
30. Chocos
31. Hawai orange (HO)
32. Esmeralda (E)
33. Ceasor violet (CV)
34. Rembolina (Pink and Green)
35. Corolix (Red and Green)
36. Grace (white)
37. Diva pink (DV)
38. Elan red (ER)
39. Flirt
40. Jewel

Acropolis white

Carrie

TR x MW

PR x DT

Dragon Tongue

PR x OG

KR x LR

Liver Red

Plate 1. Different genotypes of *Anthurium andreanum* used for the study

Fla Red

OG x DT

PR x DT (2)

PR x FR

PR x LR

NO x DT

Orange Glory

W x LJ

Plate 1. (Continued) Different genotypes of *Anthurium andreanum* used for the study

Pompon Red

Kalimpong Orange

LJ

LR x PR

Agni Hotri

Lucia Pink

Nitta Orange

Gold Spark

Plate 1. (Continued) Different genotypes of *Anthurium andreanum* used for the study

Chekas

Vezuvious Red

Boroque

Arun Gold

Geisha white

Chocos

Hawiian Orange

Esmeralda

Plate 1. (Continued) Different genotypes of *Anthurium andreanum* used for the study

Ceasor Violet

Rembolina (Pink and Green)

Corolix (Red and Green)

Grace (White)

Diva Pink

Elan Red

Flirt

Jewel

Plate 1. (Continued) Different genotypes of *Anthurium andreanum* used for the study

3.1.2 METHODS

3.1.2.1 a. Evaluation of genotypes to identify suitable parents for hybridization

The selected plants were raised in pot culture experiment under completely randomised design with three replications. Fifteen parent varieties will be identified based on morphological and floral characters for hybridization(Plate.2).

3.1.2.2 b. Hybridization

Inter varietal crossing in all possible combinations (depending upon the anther emergence) involving the 15 selected commercially important anthurium varieties showing variations in spathe colour, shape and size and other commercially valuable morphological characters.

3.1.2.2.1 Hybridization Technique in Anthurium

The inflorescence in anthurium is called spadix, with an inflorescence axis (candle) and an enveloping modified bract called spathe, which is brightly coloured and highly ornamental. The true flowers of anthurium are bisexual and are embedded in the candle. About 150-350 of them present in a single candle. The flowers show a clear protogynous condition and so no emasculation was needed. The spadix of the selected female parent was protected using a butter paper cover before the starting of the female phase to prevent unwanted pollen. When the female phase started as indicated by the viscous exudates from the lower flowers, pollen was collected from the male parent and brushed on to the candle of the female parent with wet hand.

The pollination was done between 8 and 9 am as the anthesis occurred during this time. Repeated pollinations were done over a period of five to seven days and the spadix was kept bagged with butter paper cover for one more month. Each pollinated spadix was clearly labelled showing the cross and date of crossing. The 210 possible cross combinations are shown in Table 1.

The bottom one-third of each pot was filled with broken bricks and the middle one third portion was filled with a mixture of coarse sand, broken bricks,

Plate 2. General view of experimental field

Table 1. Possible cross combinations between fifteen selected parents

	AW	C	PR x DT	DT	PR x OG
AW	x	AW x C	AW x [PR x DT]	AW x DT	AW x [PR x OG]
C	C x AW	x	C x [PR x DT]	C x DT	C x [PR x OG]
PR x DT(1)	[PR x DT(1)] x AW	[PR x DT(1)] x C	x	[PR x DT(1)] x DT	[PR x DT(1)] x [PR x OG]
DT	DT x AW	DT x C	DT x [PR x DT]	x	DT x [PR x OG]
PR x OG	[PR x OG] x AW	[PR x OG] x C	[PR x OG] x [PR x DT]	[PR x OG] x DT	x
KR x LR	[KR x LR] x AW	[KR x LR] x C	[KR x LR] x [PR x DT]	[KR x LR] x DT	[KR x LR] x [PR x OG]
LR	LR x AW	LR x C	LR x [PR x DT]	LR x DT	LR x [PR x OG]
OG x DT	[OG x DT] x AW	[OG x DT] x C	[OG x DT] x [PR x DT]	[OG x DT] x DT	[OG x DT] x [PR x OG]
PR x DT(2)	[PR x DT(2)] x AW	[PR x DT(2)] x C	[PR x DT(2)] x [PR x DT]	[PR x DT(2)] x DT	[PR x DT(2)] x [PR x OG]
PR x LR	[PR x LR] x AW	[PR x LR] x C	[PR x LR] x [PR x DT]	[PR x LR] x DT	[PR x LR] x [PR x OG]
LJ	LJ x AW	LJ x C	LJ x [PR x DT]	LJ x DT	LJ x [PR x OG]
CV	CV x AW	CV x C	CV x [PR x DT]	CV x DT	CV x [PR x OG]
FR	FR x AW	FR x C	FR x [PR x DT]	FR x DT	FR x [PR x OG]
Flirt	Flirt x AW	Flirt x C	Flirt x [PR x DT]	Flirt x DT	Flirt x [PR x OG]
E	E x AW	E x C	E x [PR x DT]	E x DT	E x [PR x OG]

Table 1. Continued

♀ \ ♂	KR x LR	LR	OG x DT	PR x DT(2)
AW	AW x [KR x LR]	AW x LR	AW x [OG x DT]	AW x [PR x DT(2)]
C	C x [KR x LR]	C x LR	C x [OG x DT]	C x [PR x DT(2)]
PR x DT(1)	[PR x DT(1)] x [KR x LR]	[PR x DT(1)] x LR	[PR x DT(1)] x [OG x DT]	[PR x DT(1)] x [PR x DT(2)]
DT	DT x [KR x LR]	DT x LR	DT x [OG x DT]	DT x [PR x DT(2)]
PR x OG	[PR x OG] x [KR x LR]	[PR x OG] x LR	[PR x OG] x [OG x DT]	[PR x OG] x [PR x DT(2)]
KR x LR	x	[KR x LR] x LR	[KR x LR] x [OG x DT]	[KR x LR] x [PR x DT(2)]
LR	LR x [KR x LR]	x	LR x [OG x DT]	LR x [PR x DT(2)]
OG x DT	[OG x DT] x [KR x LR]	[OG x DT] x LR	x	[OG x DT] x [PR x DT(2)]
PR x DT(2)	[PR x DT(2)] x [KR x LR]	[PR x DT(2)] x LR	[PR x DT(2)] x [OG x DT]	x
PR x LR	[PR x LR] x [KR x LR]	[PR x LR] x LR	[PRxLR] x [OG x DT]	[PRxLR] x [PR x DT(2)]
LJ	LJ x [KR x LR]	LJ x LR	LJ x [OG x DT]	LJ x [PR x DT(2)]
CV	CV x [KR x LR]	CV x LR	CV x [OG x DT]	CV x [PR x DT(2)]
FR	FR x [KR x LR]	FR x LR	FR x [OG x DT]	FR x [PR x DT(2)]
Flirt	Flirt x [KR x LR]	Flirt x LR	Flirt x [OG x DT]	Flirt x [PR x DT(2)]
E	E x [KR x LR]	E x LR	E x [OG x DT]	E x [PR x DT(2)]

Table 1. Continued

	PR x LR	LJ	CV	FR	Flirt	E
AW	AW x [PR x LR]	AW x LJ	AW x CV	AW x FR	AW x Flirt	AW x E
C	C x [PR x LR]	C x LJ	C x CV	C x FR	C x Flirt	C x E
PR x DT(1)	[PR x DT(1)] x [PR x LR]	[PR x DT(1)] x LJ	[PR x DT(1)] x CV	[PR x DT(1)] x FR	[PR x DT(1)] x Flirt	[PR x DT(1)] x E
DT	DT x [PR x LR]	DT x LJ	DT x CV	DT x FR	DT x Flirt	DT x E
PR x OG	[PR x OG] x [PR x LR]	[PR x OG] x LJ	[PR x OG] x CV	[PR x OG] x FR	[PR x OG] x Flirt	[PR x OG] x E
KR x LR	[KR x LR] x [PR x LR]	[KR x LR] x LJ	[KR x LR] x CV	[KR x LR] x FR	[KR x LR] x Flirt	[KR x LR] x E
LR	LR x [PR x LR]	LR x LJ	LR x CV	LR x FR	LR x Flirt	LR x E
OG x DT	[OG x DT] x [PR x LR]	[OG x DT] x LJ	[OG x DT] x CV	[OG x DT] x FR	[OG x DT] x Flirt	[OG x DT] x E
PR x DT(2)	[PR x DT(2)] x [PR x LR]	[PR x DT(2)] x LJ	[PR x DT(2)] x CV	[PR x DT(2)] x FR	[PR x DT(2)] x Flirt	[PR x DT(2)] x E
PR x LR	x	[PR x LR] x LJ	[PRxLR] x CV	[PRxLR] x FR	[PRxLR] x Flirt	[PRxLR] x E
LJ	LJ x [PR x LR]	x	LJ x CV	LJ x FR	LJ x Flirt	LJ x E
CV	CV x [PR x LR]	CV x LJ	x	CV x FR	CV x Flirt	CV x E
FR	FR x [PR x LR]	FR x LJ	FR x CV	x	FR x Flirt	FR x E
Flirt	Flirt x [PR x LR]	Flirt x LJ	Flirt x CV	Flirt x FR	x	Flirt x E
E	E x [PR x LR]	E x LJ	E x CV	E x FR	E x Flirt	x

dried coconut husk pieces and charcoal mixed in 7:1:1:1 ratio, respectively. The plants with well developed roots were placed over this and the plants were anchored with more potting mixture. Coarse sand was used in the potting medium and the method of planting ensured 100 per cent drainage.

Artificial shade of 75 per cent was provided with black polypropylene agro-shade netting. Mist irrigation was provided two to three times each day depending on temperature conditions.

Regular applications of fertilizers were given at weekly intervals. NPK mixture 17:17:17 was applied at a strength of 5 g/l as aqueous solution once in a month. Additional nutrients like diluted cowdung water and fermented and diluted ground nut-neem cake mixture were given once a month. For preparing the latter, 2 kg of ground nut cake and 4 kg neem cake were fermented in 5 litres of water for two days. The mixture was then diluted by adding 245 litres of very dilute cowdung water. About 200 ml of the sieved fertilizer solution was then applied to each pot.

3.1.2.3 Plant Protection

1. For the control of blight or anthracnose by *Colletotrichum gloeosporioides* regular application of following chemicals were used.

    a. Bavistin 50 per cent WP @ 2g l^{-1} or

    b. Indofil M-45 2 g l^{-1}

2. Dipping the roots of plants in Indofil M-45 at the time of planting helped to avoid soil borne diseases.

3. *Pseudomonas fluorescens* @ 2 per cent was applied as prophylactic measure against bacterial blight caused by *Xanthomonas axonopodis* pv. *dieffenbachiae* at weekly intervals.

4. Need based application of metacid (2g l^{-1}) or Nuvacron (2g l^{-1}) were used to control leaf feeding caterpillars and grass hoppers. Mites were controlled using Kelthane (2ml l^{-1}).
5. Snails and slugs were controlled by picking by hand and also by the application of furadan 3 g @ 2-3 g per pot.

3.1.3 Morphological Studies

The plant materials with stabilized vegetative and floral characters were used for taking all the observations. Observations on the following 18 characters (vegetative and floral characters) were recorded and their mean values were taken.

3.1.3.1 Morphological characters

3.1.3.1.1 Plant height

Plant height in centimeters were measured from the base of the plant to the top of the top most leaf.

3.1.3.1.2 Leaf size/leaf area

The maximum length and breadth of the third leaf were used for the estimation of leaf area. The third leaf was chosen as this would be the leaf, which will be fully unfurled and has achieved its full growth and spread of the leaf blade.

The leaf area of the 40 genotypes were measured by applying linear regression.

$$y = 9.53 + 0.64\ x$$

Where y is the leaf area and x = maximum leaf length x maximum leaf breadth (Mayadevi, 2001).

3.1.3.1.3 Internodal length

The distance between two nodes was measured from the base of the plant and recorded in centimeters.

3.1.3.1.4 Number of suckers per plant

The ability of the plant to produce new suckers from the base of the mother plant was observed and the number of suckers was recorded.

3.1.3.1.5 Number of leaves/ spadices per plant

The number of leaves/ spadices produced during the one year period was observed and recorded.

3.1.3.1.6 Days from emergence to maturity of leaves

Days from the emergence of the leaf to the maturity of leaves were recorded.

3.1.3.1.7 Colour of petiole and young leaf

The colour of petiole and young leaf of each genotype was recorded by visual observation when the leaves were not opened fully.

3.1.3.1.8 Pest and disease incidence

The pest and disease incidence among the genotypes during the three year period was observed.

3.1.3.2 Floral characters

3.1.3.2.1 Days from emergence to maturity of inflorescence

The time taken from the emergence of infloresence to its full maturity was recorded.

3.1.3.2.2 Spathe colour

The spathe colour of each variety was recorded by visual observation.

3.1.3.2.3 Spathe texture

The degree of blistering, thickness of spathe, presence of veins and the glossiness of spathe were recorded to differentiate the spathe texture of each variety.

3.1.3.2.4 Spathe size

The spathe size of each variety was recorded by using standard graph sheet method.

3.1.3.2.5 Total Anthocyanin content

Estimation of anthocyanin was done as per the method described by Rangana (1977). The initial step was alcoholic extraction of the plant material (spathe). One gram of the spathe sample from each treatment was extracted with ethanolic hydrochloric acid, filtered through a Buchner funnel using Whatman

No. 1 filter paper and the filtrate was then diluted with ethanolic hydrochloric acid to 50 ml to yield optical density values within the optimum range of the spectrophotometer (535 nm). The anthocyanin content was then calculated using the following relationship and the quantity was expressed as mg per 100 gm of the sample.

Total OD per 100 g of sample (X) = [(Absorbance at 535nm) x (Volume made up of the extract used for colour development) x (Total volume) x 100] ÷ [Volume (ml of the extract) used x Weight of sample taken]

The absorbance of a solution containing 1 mg per ml is equal to 98.2 (constant).

Therefore,

Total anthocyanin in mg per 100 g of the sample = $\frac{X}{98.2}$

3.1.3.2.6 Spadix colour

Visual observation was used to record the candle colours.

3.1.3.2.7 Spadix length

Candle length was measured in centimeters from the base of the candle to its tip.

3.1.3.2.8 Inclination of candle with the spathe

The angle between the base of the candle to the plane of the subtending spathe was taken with the help of a protractor.

3.1.3.2.9 Number of flowers per spadix

The total number of flowers arranged spirally on the candle from the base to the tip was counted and recorded.

3.1.3.2.10 Life of spadix

The period between the first day of emergence of inflorescence upto to the time of its yellowing, withering of spathe and shrivelling of candle was recorded as the life of spadix or longevity of spadix.

3.1.3.2.11 Days to initiation of female phase

The number of days from the emergence of the spathe to the first emergence of mature stigmas of the basal flowers, identified by the presence of honey dew or stigmatic droplets was recorded as the days to initiation of female phase.

3.1.3.2.12 Days to inter phase

The duration between the end of female phase and the emergence of anthers from the basal flowers, indicating the start of male phase, was recorded as the days of interphase.

3.1.3.2.13 Duration of male phase

The period in days for the emergence of the first anthers in the spadix to the emergence of its last anthers was recorded.

3.1.3.2.14 Type of inflorescence axis

Length, nature and strength of inflorescence axis in each variety were observed and recorded.

3.1.3.2.15 Pollen fertility

Pollen fertility was assessed using acetocarmine staining method. Pollen grains were collected during the male phase from all the parents and hybrids and stained with 1:1 glycerine - acetocarmine stain (2 per cent). Five slides were made for each variety and from each slide, ten microscopic fields were scored and the data recorded. Unstained, undersized, partially stained and shrivelled pollen grains were scored as sterile and the uniformly stained, properly filled pollen as fertile. Fertility of each variety was estimated as percentage of the number of fertile pollen grains to the total number of pollen grains scored.

The pollen fertility was calculated as,

$$\text{Pollen fertility} = \frac{\text{No. of well filled and uniformly stained pollen grains}}{\text{Total number of pollen grains}} \times 100$$

3.1.3.2.16 Pollen Morphology (size and shape)

Pollen grains were measured using ocular micrometer after caliberation. Caliberation was done with the help of stage micrometer to obtain the measurement of ocular micrometer division and converted it to μ.

The diameter of the pollen grains (100 pollen grains) were then measured. Based on this mean, standard deviation (σ) and standard error[$\sigma/\sqrt{n}$] were calculated to find out the average diameter of the pollen grain.

Average diameter = Mean ± Standard error

The pollen shape of each variety was recorded by visual observation using microscope

3.1.3.2.17 Percentage of spadix bearing berries

Successfully fertilized inflorescence that remained healthy with strong and green peduncles were noted and their percentage was calculated as

$$\frac{\text{The number of spadices bearing berries}}{\text{Number of spadices pollinated}} \times 100$$

3.1.3.2.18 Number of berries/ spadix

The number of berries in each successfully fertilized spadix was counted and recorded.

3.1.3.2.19 Percentage of berry set per spadix

The percentage of flowers showing fruit set to the total number of flowers pollinated in a spadix was calculated and recorded as the percentage of fruit set. Hundred per cent of the flowers were assumed to be pollinated in a spadix pollinated four times, 90 per cent in candles pollinated three times, 60 per cent for two and 30 per cent for one pollination. The number of

pollinations done varied depending upon the availability of receptive stigma and fresh pollen.

3.1.3.2.20 Number of Seeds per Berry

The number of seeds in each ripe berry was recorded.

3.1.3.2.21 Seed Size

The length and breadth of seeds were measured in millimeters and recorded. Separate measurements were taken for the seeds of single seeded and double seeded berries.

3.1.4 Statistical Analysis

3.1.4.1 Biometrical Technique Applied

The data collected were subjected to statistical analysis using variance – covariance analysis. Heritability coefficient, genetic advance and phenotypic, genotypic and environmental correlation coefficients were estimated.

3.1.4.1.1 Analysis of Variance/Covariance

With two characters X and Y measured in g genotypes raised in completely randomized design with r replications, the variance, covariance analysis (ANACOVA) is as follows:

Source	df	Mean square		
		x	y	xy
Between genotypes	(g-1)	G_{xx}	G_{yy}	G_{xy}
Error	(r-1) (g-1)	E_{xx}	E_{yy}	E_{xy}

The estimates of components of variance and covariance are given below:

Variance/ Covariance of	Genotypic	Environmental	Phenotypic
X	$\sigma^2_{gx} = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$
Y	$\sigma^2_{gy} = \frac{G_{yy} - E_{yy}}{r}$	$\sigma^2_{ey} = E_{yy}$	$\sigma^2_{py} = \sigma^2_{gy} + \sigma^2_{ey}$
XY	$\sigma_{gxy} = \frac{G_{xy} - E_{xy}}{r}$	$\sigma_{exy} = E_{xy}$	$\sigma_{pxy} = \sigma_{gxy} + \sigma_{exy}$

3.1.4.1.2 Coefficient of Variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) for a trait X were estimated as

$$GCV = \frac{\sigma_{gx}}{\bar{x}} \times 100$$

$$PCV = \frac{\sigma_{px}}{\bar{x}} \times 100$$

Where,

σ_{gx} = genotypic standard deviation

σ_{px} = phenotypic standard deviation

$\bar{x}$ = mean of the character under study

3.1.4.1.3 Heritability

Heritability (H^2) in broad sense was estimated as the proportion of heritable component of variation. Heritability for the chracter in broad sense was calculated as a percentage based on the formula given by Jain (1982).

$$\text{Heritability coefficient, } H^2 \text{ (in broad sense)} = \frac{\sigma_{gx}^2}{\sigma_{px}^2} \times 100$$

where σ_{gx}^2 and σ_{px}^2 are the genotypic and phenotypic variance of that character.

Allard (1960) classification

< 30 percent	- Low
30-60 percent	- Medium
>60 percent	- High

$$\text{Genetic advance as percentage of mean (GA)} = \frac{kH^2\ \sigma_{px}}{\bar{x}} \times 100$$

Where k is the selection differential whose value is 2.06 if five per cent selection is to be practiced (Miller *et. al.*, 1958). H^2 is heritability in broad sense, σp_x is phenotypic standard deviation and x is the mean of the character over all varieties.

Genetic advance as percentage were categorized into low (<20 %) and high (>20 %) as suggested by Robinson *et al.* (1949).

3.1.4.1.4 Correlation Analysis

The correlation coefficients (phenotypic, genotypic and environmental) between two characters denoted as x and y were worked out as

$$\text{Genotype correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{cy}}$$

Where σ_{gxy}, σ_{pxy} and σ_{exy} are the genotypic, phenotypic and environmental co-variances between the characters x and y. σ_{gx}, σ_{px} and σe_x are the genotypic, phenotypic and environmental standard deviations for the character x and σ_{gy}, σ_{py} and σ_{ey} are the genotypic, phenotypic and environmental standard deviations for the character y.

3.1.4.1.5 *Path Coefficient Analysis*

The direct and indirect effect of component character on yield were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959).

3.1.4.1.6 *Mahalanobis D^2 Analysis*

Genetic divergence was studied using Mahalanobis D^2 statistic as described by Rao (1952). The genotypes were clustered by Tochers method.

3.1.4.1.7 *Selection index*

The various genotypes were discriminated based on nine characters using the selection index developed by Smith (1947) using the discriminant function of Fischer (1936).

The selection index is described by the function $I = b_1x_1 + b_2x_2 + \ldots + b_kx_k$ where $x_1, x_2, \ldots x_k$ are the phenotypic values. Merit of a plant measured in terms of its genetic worth as $H = a_1G_1 + a_2G_2 + \ldots + a_kG_k$ where $G_1, G_2, \ldots G_k$ are the genotypic values of the plant with respect to the characters $X_1, X_2, \ldots X_k$ and $a_1, a_2, \ldots a_k$ are the economic weightages. H denotes the genetic worth of the plant. The economic weightage assigned to each character is assumed to be equal to unity *i.e.*, $a_1, a_2, \ldots a_k = 1$. The regression coefficients $b_1, b_2, \ldots b_k$ are estimated in such a way that the correlation between H and I is maximum. The procedure will reduce to an equation of the form $b = P^{-1}Ga$, where P is the phenotypic, G is the genotypic variance covariance matrix respectively and a is vector of ones, from which the b values were solved out.

3.2 Experiment-II: Cross compatibility analysis

3.2.1 Materials

All the fifteen selected genotypes were crossed among themselves and identified the compatible crosses and seeds of these successful crosses were utilized for the study.

3.2.2 Methods

The successful viable crosses were raised in pot culture experiment under completely randomised design with five replications. Compatibility analysis was done based on seed germination percentage, seedling viability and survival percentage till flowering.

3.2.3 Morphological studies

Observations on the following eight characters (seedling and vegetative) were recorded and their mean values were taken.

3.2.3.1 Seed Germination (%)

The mucilage around the seeds was removed before sowing and the seeds were kept in moist cotton in petridishes to induce germination. The number of seeds that germinated within four to nine days was noted and percentage of germination calculated as percentage of number of seeds germinated to number of seeds kept for germination.

3.2.3.2 Seedling viability

The number of seedlings survived for four to six months age was noted and percentage of seedling viability (seedling survival) calculated as number of seeds survived to number of seeds germinated.

3.2.3.3 Days from emergence to maturity of leaves

Days from the emergence of the leaf to the maturity of leaves were recorded.

3.2.3.4 Number of leaves

The number of leaves per plant was noted and recorded.

3.2.3.5 Leaf area

The maximum length and breadth of the third leaf were used for the estimation of leaf area. The third leaf was chosen as this would be the leaf, which will be fully unfurled and has achieved its full growth and spread of the leaf blade.

The leaf area of the seedlings measured by applying linear regression.

$$y = 9.53 + 0.64\ x$$

Where y is the leaf area and x = maximum leaf length x maximum leaf breadth (Mayadevi, 2001).

3.2.3.6 Colour of petiole and young leaf

The colour of petiole and young leaf of each genotype was recorded by visual observation when the leaves were not opened fully.

3.2.3.7 Internodal length

The distance between two nodes was measured from the base of the plant and recorded in centimeters.

3.2.3.8 Seedling survival till flowering

The number of seedlings survived for more than six months age was noted and recorded.

3.2.4 Statistical Analysis

3.2.4.1 Compatibility studies

Compatibility reactions from the attempted crosses were converted into a linear scale.

Results

4. RESULTS

The experimental data were collected on various morphological characters of forty genotypes of *Anthurium andreanum* for the present study. The recorded observations were statistically analysed and the results obtained are presented here.

The results of the present investigation are presented under two major headings.

1. Evaluation of genotypes to identify suitable parents for hybridization
2. Cross compatibility analysis

4.1 Evaluation of genotypes to identify suitable parents for hybridization

The performance of forty genotypes of *Anthurium andreanum* were evaluated in green house, each genotype being replicated thrice. The data were statistically analysed and the results are presented in the following sub heads.

4.1.1 Evaluation of genotypes for their performance

4.1.2 Estimation of variability components

4.1.3 Estimation of heritability and genetic advance

4.1.4 Correlation among different characters

4.1.5 Path coefficient analysis

4.1.6 Cluster analysis

4.1.7 Selection index

4.1.1 Evaluation of genotypes for their performance

The analysis of variance revealed significant genotypic differences among the varieties for all the characters studied and the results are furnished in Table. 2. The mean performance of each of the 40 genotypes for 18 characters (morphological, floral and qualitative characters) under the study were worked out and furnished in Table.3 (a, b and c).

Table 2. Analysis of variance of vegetative (1-6) and floral (7-18) characters in *Anthurium andreanum* genotypes

Sl. No.	Characters	Degrees of freedom	Mean square	
			Genotype 39	Error 80
1	Plant height (cm)		123.76**	11.95
2	Leaf size/leaf area (cm^2)		14065.63**	581.32
3	Internodal length (cm)		0.16**	0.013
4	Number of suckers per plant		2.53**	0.14
5	Number of leaves per plant		1.35**	0.28
6	Days from emergence to maturity of leaves		22.04**	3.02
7	Days from emergence to maturity of inflorescence		19.77**	4.55
8	Spathe size (cm^2)		1870.84**	121.59
9	Total Anthocyanin content (mg/g)		34406.61**	40.52
10	Spadix length (cm)		6.57**	0.32
11	Inclination of candle with the spathe (degrees)		320.59**	23.49
12	Number of flowers/Spadix		26698.33**	1132.27
13	Life of spadix (days)		519.41**	25.59
14	Days to initiation of female phase		8.45**	0.96
15	Duration of interphase		6.90**	0.74
16	Duration of male phase		12.33**	1.07
17	Pollen fertility (per cent)		314.95**	5.53
18	Pollen size (μ)		18.64**	1.18

*Significant at five per cent level ** Significant at one per cent level

4.1.1.1 Morphological characters

4.1.1.1.1 Plant height

The genotype Nitta Orange recorded the lowest plant height (17.33 cm) which was on par with Agnihotri (17.78 cm), Rembolina (18.33 cm), Chocos (19 cm), Vezuvious Red (20.06 cm), Arun Gold (21.83 cm), Corolix (22 cm) and W x LJ (22.83 cm). The highest mean plant height was recorded by Liver Red (43.25 cm) which was on par with PR x DT (2) (41.33 cm), PR x DT (1) (39.22 cm), PR x LR (39 cm) and OG x DT (37.66 cm).

4.1.1.1.2 Leaf size/leaf area

The leaf area was minimum for the genotype Rembolina (58.62 cm^2) which was on par with Corolix (81.1 cm^2) and maximum for the genotype PR x DT (1) (343.56 cm^2) which was on par with PR x OG (314.5 cm^2), OG x DT (312.17 cm^2) and PR x DT (2) (308.37 cm^2).

4.1.1.1.3 Internodal length

The minimum value of 0.97 cm was exhibited by the genotype Agnihotri which was on par with W x LJ (0.98). The maximum value was exhibited by Esmeralda (2.02 cm) which was on par with PR x DT (1) (1.98 cm) and PR x OG (1.96 cm).

4.1.1.1.4 Number of suckers per plant

Sucker production was highest for the genotype Liver Red (3). Lowest number of suckers was produced for the genotypes Lady Jane and Esmeralda (0.67). Number of suckers ranged from 0 to 3 and 50 per cent genotypes did not produce any suckers during the period under study.

4.1.1.1.5 Number of leaves/spadices per plant

Lowest number of leaves/spadices per plant was produced by the genotype Chocos (4.55) followed by Arun Gold and W x LJ (4.83) while the maximum for the genotype Rembolina (7.42) followed by Grace (7.37) and PR x OG (7.05).

Table 3a Vegetative character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	X_1	X_2	X_3	X_4	X_5	X_6
1	Acropolis white	27.00	196.66	1.72	0.00	5.44	32.66
2	Carrie	30.00	177.14	1.67	0.00	5.89	26.78
3	TR x MW	29.50	193.80	1.59	1.17	6.28	35.77
4	PR x DT (1)	39.22	343.56	1.98	1.33	5.78	33.89
5	Dragon Tongue	25.11	217.14	1.52	1.67	5.11	30.72
6	PR x OG	36.78	314.50	1.96	2.83	7.05	25.89
7	KR x LR	31.17	268.06	1.65	0.00	6.11	34.83
8	Liver Red	43.25	302.38	1.72	3.00	6.33	29.83
9	Fla Red	26.17	192.38	1.63	0.00	5.78	28.94
10	OG x DT	37.66	312.17	1.69	1.17	6.42	33.40
11	PR x DT (2)	41.33	308.37	1.71	1.17	5.52	31.47
12	PR x FR	33.67	191.40	1.46	1.33	6.47	32.22
13	PR x LR	39.00	253.39	1.57	2.00	5.93	34.94
14	NO x DT	28.00	178.09	1.63	1.33	6.19	30.41
15	Orange Glory	26.00	118.38	1.33	1.33	6.20	32.44
16	W x LJ	22.83	101.43	0.98	2.17	4.83	33.71
17	Pompon Red	34.83	175.23	1.52	1.83	6.11	30.33
18	Kalimpong Orange	31.83	130.19	1.23	2.50	5.33	31.33
19	Lady Jane	28.67	240.45	1.77	0.67	6.27	35.17
20	LR x PR	26.83	181.25	1.35	1.67	5.42	34.03
21	Agnihotri	17.78	124.06	0.97	0.00	5.67	36.60
22	Lucia pink	24.25	149.15	1.60	0.00	6.50	31.39
23	Nitta Orange	17.33	127.48	1.52	1.00	5.33	31.78
24	Gold Spark	27.33	158.60	1.42	0.00	6.08	33.78
25	Chekas	26.50	114.56	1.48	0.00	6.58	30.39
26	Vezuvious Red	20.06	135.64	1.44	0.00	5.61	35.55
27	Boroque	27.33	197.42	1.68	0.00	5.33	28.94
28	Arun Gold	21.83	130.17	1.53	0.00	4.83	29.89
29	Geisha white	24.00	198.37	1.80	1.17	5.50	28.15
30	Chocos	19.00	99.73	1.42	0.00	4.55	29.39
31	Hawaiian orange	32.33	165.01	1.70	0.00	5.50	31.39
32	Esmeralda	28.67	152.99	2.02	0.67	6.92	29.11
33	Ceasor violet	29.17	185.26	1.72	0.00	6.00	28.39
34	Rembolina (Pink and Green)	18.33	58.62	1.25	0.00	7.42	26.89
35	Corolix (Red and Green)	22.00	81.10	1.27	0.00	6.78	34.88
36	Grace (white)	30.67	129.96	1.40	0.00	7.37	32.89
37	Diva pink	24.67	131.98	1.48	0.00	5.56	32.33
38	Elan red	26.44	185.94	1.62	0.00	5.58	33.93
39	Flirt	32.50	163.03	1.70	0.00	6.83	35.31
40	Jewel	31.50	117.32	1.32	0.00	6.00	32.50
	Mean	28.514	180.059	1.551	0.750	5.960	31.806
	SE	2.823	19.686	0.093	0.306	0.432	1.419
	CD	5.6227	39.1754	0.1833	0.616	0.8606	2.8248

X_1 Plant height (cm)
X_2 Leaf size/leaf area (cm^2)
X_3 Internodal length (cm)
X_4 Number of suckers per plant
X_5 Number of leaves/spadices per plant
X_6 Days from emergence to maturity of leaves

4.1.1.1.6 Days from emergence to maturity of leaves

The least number of days for maturity of leaves was taken by PR x OG (25.89) which was on par with the variety Carrie (26.78), Rembolina (26.89), Geisha white(28.15) and Ceasor violet(28.39). The maximum number of days was taken by the genotype Agnihotri (36.6) followed by TR x MW (35.77), Vezuvious Red (35.55), Flirt (35.31) and Lady Jane (35.17).

4.1.1.1.7 Pest and disease incidence

No major pest and diseases were noticed in the experimental field during the period of study. Leaf spot and bacterial blight symptoms were found in some varieties. Bacterial blight incidence was more in Hawaiian orange, Acropolis White, Ceasor Violet, Esmaralda, Arun Gold, Geisha White, corolix and Agnihotri. Leaf spot damage was more in Esmeralda, Grace and Gold Spark. Among the genotypes sucking pest incidence was less it is mainly due to application of pesticides at monthly intervals. Snails and slugs were the common pests observed in field during the study. Leaf and spathe of Chocó and Vezuvious Red were most effected by grubs (young ones of beetles) and leaf eating insects. Application of *Pseudomonas* culture in pots was found to be effective in controlling fungal diseases.

4.1.1.2 Floral characters

4.1.1.2.1 Days from emergence to maturity of inflorescence

The genotype Grace recorded the lowest mean value (23.83) for this character and highest for the genotype Liver Red (33.39).

4.1.1.2.2 Spathe size (cm^2)

The maximum spathe size was observed for Acropolis White (123.43 cm) which was on par with Geisha white (118.18 cm), Carrie (115.44 cm), PR x DT (1) (110.46 cm) and Boroque (107.00 cm) and the minimum for the genotype W x LJ (24.44 cm) which was on par with LR x PR (27.10 cm) and Orange Glory (32.11 cm)

Table 3b Floral character differentiation in *Anthurium andreanum* genotypes

Sl. No.	Genotypes	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
1	Acropolis white	31.80	123.43	23.35	6.97	49.17	420.00
2	Carrie	27.44	115.44	63.43	7.13	60.50	396.67
3	TR x MW	26.55	46.77	178.39	4.03	35.83	330.67
4	PR x DT (1)	25.55	110.46	226.68	8.38	57.50	498.67
5	Dragon Tongue	26.94	60.41	258.59	5.58	65.50	371.33
6	PR x OG	30.56	58.02	35.02	6.85	49.13	446.67
7	KR x LR	27.39	59.37	270.30	6.43	50.50	518.67
8	Liver Red	33.39	93.52	386.23	7.19	55.83	494.67
9	Fla Red	25.03	79.87	111.88	6.80	38.33	410.67
10	OG x DT	29.50	99.54	36.98	8.77	45.00	514.67
11	PR x DT (2)	29.55	91.88	241.03	7.80	58.61	502.67
12	PR x FR	28.69	81.65	179.55	6.70	45.00	350.67
13	PR x LR	31.22	57.85	482.05	4.81	43.60	414.00
14	NO x DT	30.17	69.76	224.44	6.08	41.67	338.67
15	Orange Glory	30.00	32.11	16.94	3.58	35.33	286.00
16	W x LJ	26.55	24.44	9.73	3.86	75.00	292.00
17	Pompon Red	24.89	44.68	113.19	5.34	37.50	342.00
18	Kalimpong Orange	24.50	44.08	26.91	5.50	40.00	372.00
19	Lady Jane	27.11	46.99	53.67	8.06	50.78	440.00
20	LR x PR	31.10	27.10	170.41	3.27	39.50	196.00
21	Agni Hotri	32.94	48.24	90.75	4.62	55.33	238.67
22	Lucia pink	30.17	78.90	33.98	4.32	51.17	264.00
23	Nitta Orange	26.89	78.66	47.98	4.23	46.33	340.67
24	Gold Spark	26.33	69.54	26.91	3.88	71.67	265.33
25	Chekas	26.22	75.08	165.89	3.96	64.00	273.33
26	Vezuvious Red	25.11	70.54	91.45	4.44	75.67	221.33
27	Boroque	24.33	107.00	43.91	4.59	58.33	380.00
28	Arun Gold	30.39	47.82	216.63	4.03	59.50	259.33
29	Geisha white	27.33	118.18	23.99	5.84	50.17	378.67
30	Chocos	27.11	102.44	91.73	4.45	59.83	238.00
31	Hawaiian orange	30.55	76.01	47.83	5.45	55.50	413.33
32	Esmeralda	27.11	90.23	35.13	4.88	49.17	285.33
33	Ceasor violet	24.22	92.28	88.53	5.58	48.67	408.00
34	Rembolina	26.83	54.08	33.18	4.43	40.83	230.00
35	Corolix	25.22	73.43	73.94	3.71	57.50	196.00
36	Grace	23.83	64.83	31.13	3.35	57.17	231.33
37	Diva pink	24.11	74.41	31.98	4.06	40.00	221.33
38	Elan red	29.28	85.98	103.12	5.25	49.44	386.67
39	Flirt	27.17	67.12	91.45	5.37	44.17	330.67
40	Jewel	28.89	54.91	190.28	4.02	44.17	262.67
	Mean	27.799	72.427	116.714	5.340	51.323	344.034
	SE	1.742	9.003	5.197	0.462	3.957	27.474
	CD	3.4639	17.9164	10.3431	0.9117	7.8743	54.6741

X_7 Days from emergence to maturity of inflorescence

X_8 Spathe size (cm^2)

X_9 Total Anthocyanin content (mg/g)

X_{10} Spadix length (cm)

X_{11} Inclination of candle with the spathe (degrees)

X_{12} Number of flowers/Spadix

Table 3b Continued

Sl. No.	Genotypes	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
1	Acropolis white	96.17	6.49	6.61	10.36	17.25	19.89
2	Carrie	62.17	5.50	6.17	7.33	19.81	21.53
3	TR x MW	67.67	7.44	5.11	10.89	12.45	19.35
4	PR x DT (1)	101.33	4.89	8.39	10.47	11.05	22.09
5	Dragon Tongue	83.17	6.47	7.96	9.30	21.23	18.58
6	PR x OG	71.67	6.60	5.55	8.00	23.80	16.59
7	KR x LR	74.17	7.08	6.58	8.00	18.84	24.08
8	Liver Red	93.83	6.15	9.18	5.53	43.01	20.14
9	Fla Red	63.53	6.22	5.22	8.11	23.67	19.78
10	OG x DT	97.72	5.61	4.87	7.53	36.13	15.77
11	PR x DT (2)	84.50	4.83	7.89	8.17	25.08	23.00
12	PR x FR	66.00	6.50	9.17	8.23	28.71	20.87
13	PR x LR	86.92	7.50	6.57	6.33	14.19	21.25
14	NO x DT	73.67	4.55	5.77	7.87	27.70	22.97
15	Orange Glory	90.33	7.40	4.33	7.50	28.24	18.20
16	W x LJ	62.83	8.11	7.17	9.00	11.00	17.65
17	Pompon Red	70.33	6.42	5.11	6.55	19.77	17.73
18	Kalimpong Orange	54.17	5.44	6.11	4.99	25.20	17.55
19	Lady Jane	75.53	3.55	6.53	6.53	36.14	25.18
20	LR x PR	82.33	5.06	6.18	7.00	33.55	18.14
21	Agni Hotri	73.83	8.17	7.44	8.00	25.56	18.35
22	Lucia pink	64.00	6.84	7.17	8.39	20.14	18.50
23	Nitta Orange	72.37	8.20	9.22	8.89	25.61	18.56
24	Gold Spark	46.83	8.55	3.89	7.22	12.47	18.43
25	Chekas	78.53	6.89	4.67	9.44	12.40	16.12
26	Vezuvious Red	66.17	3.78	3.55	8.89	30.08	14.98
27	Boroque	78.97	10.55	5.83	5.55	9.69	18.52
28	Arun Gold	71.17	5.00	8.00	10.33	18.77	14.67
29	Geisha white	75.83	5.11	3.67	9.50	17.25	17.51
30	Chocos	77.50	6.11	4.33	8.89	25.39	17.28
31	Hawaiian orange	70.00	7.11	5.09	4.77	25.37	19.55
32	Esmeralda	77.03	7.55	7.10	4.33	9.58	16.47
33	Ceasor violet	70.67	4.00	4.50	7.00	11.92	19.84
34	Rembolina	55.67	10.44	5.75	3.67	4.58	17.75
35	Corolix	51.37	8.33	5.33	3.37	2.95	16.81
36	Grace	52.50	4.83	5.20	3.87	3.41	16.14
37	Diva pink	48.53	9.72	8.00	10.00	2.59	17.38
38	Elan red	67.83	7.00	6.22	5.17	4.49	17.85
39	Flirt	70.83	6.33	6.55	9.00	4.94	16.11
40	Jewel	66.10	4.83	7.10	10.33	5.89	15.15
	Mean	72.344	6.529	6.227	7.608	18.748	18.658
	SE	4.130	0.800	0.702	0.845	1.920	0.887
	CD	8.2201	1.5954	1.4011	1.6824	3.8194	8.2201

X_{13} Life of spadix (days)

X_{14} Days to initiation of female phase

X15 Duration of interphase

X16 Duration of male phase

X17 Pollen fertility (per cent)

X18 Pollen size (μ)

4.1.1.2.3 Total Anthocyanin content

The total anthocyanin content showed wide variation among the genotypes and it ranged from 9.73 mg/g to 482.05 mg/g. Total Anthocyanin content was highest for genotype PR x LR (482.05 mg/g) while lowest was for the genotype W x LJ (9.73 mg/g) which was on par with Orange Glory (16.94 mg/g).

4.1.1.2.4 Spadix length

Spadix length was maximum for genotype OG x DT (8.77 cm) which was on par with PR x DT (1) (8.38 cm) and Lady Jane (8.06 cm) while the minimum was for genotype LR x PR (3.27 cm) followed by Grace (3.35 cm) and Orange Glory (3.58 cm).

4.1.1.2.5 Inclination of candle with the spathe

The angle between the candle and the spathe was lowest for the genotype Orange Glory (35.33°) followed by TR x MW (35.83°) and Pompon Red (37.5°). The maximum angle observed for the genotype Vezuvious Red (75.67°) which was on par with W x LJ (75°) and Gold Spark (71.67°).

4.1.1.2.6 Number of flowers /spadix

The maximum number of flowers /spadix was observed for the genotype KR x LR (518.67) which was on par with OG x DT (514.67), PR x DT (2) (502.67), PR x DT (1) (498.67) and Liver Red(494.67). The minimum number of flowers /spadix was exhibited for the genotypes LR x PR and Corolix (196) which was followed by Vezuvious Red and Diva pink (221.33).

4.1.1.2.7 Life of spadix

The highest mean value for the life of the spadix was recorded by PR x DT (1) (101.33 days) which was on par with OG x DT (97.72 days), Acropolis white (96.17 days) and Liver Red(93.83 days). The lowest mean recorded for the Gold Spark (46.83 days) which was on par with Diva pink(48.53 days), Corolix(51.37 days), Grace(52.5 days) and Kalympong Orange (54.17 days).

4.1.1.2.8 Days to initiation of female phase

The mean number of days to initiation of female phase ranged from 3.55 to 10.55. The genotype Lady Jane recorded the lowest mean value (3.55) for this character followed by Vezuvious Red (3.78), Ceasor Violet (4.00) and NO x DT (4.55). The highest mean value was recorded for the genotype Boroque (10.55) which was on par with the variety Rembolina (10.44) and Diva pink (9.72).

4.1.1.2.9 Days to interphase

The highest mean number of days to interphase was shown by Nitta Orange (9.22) which was on par with Liver Red (9.18), PR x FR (9.17), PR x DT (1) (8.39), Diva pink(8.00), Arun Gold (8.00), Dragon's Tongue (7.96) and PR x DT (2) (7.89). The lowest mean number of days to interphase was shown by Vezuvious Red (3.55) which was on par with Geisha white (3.67), Gold Spark (3.89), Chocos and Orange Glory(4.33), Ceasor violet(4.5), Chekas (4.67) and OG x DT (4.87).

4.1.1.2.10 Duration of male phase

The lowest mean duration of male phase was recorded by Corolix (3.37) which was on par with Rembolina (3.67), Grace(3.87), Esmeralda(4.33), Hawaian orange (4.77) and Kalympong Orange (4.99). The highest mean duration of male phase was obtained for the genotype TR x MW (10.89) followed by PR x DT (1) (10.47), Acropolis white (10.36), Jewel and Arun Gold(10.33).

4.1.1.2.11 Pollen fertility

Comparison of pollen fertility estimated using acetocarmine method revealed that Liver Red had the highest pollen fertility of 43.01 per cent followed by Lady Jane (36.14 per cent). The lowest value recorded for Diva pink (2.59 per cent) which was on par with Corolix (2.95 per cent), Grace (3.41 per cent), Elan red (4.49 per cent), Rembolina (4.58 per cent), Flirt (4.94 per cent) and Jewel (5.89 per cent).

4.1.1.2.12 Pollen size and shape

The mean size of the pollen ranged from 14.67μ in Arun Gold to 25.18 μ in Lady Jane. The genotypes Vezuvious Red (14.98 μ), Jewel (15.15 μ), OG x DT (15.77 μ), Flirt (16.11 μ), Chekas (16.12 μ) and Grace (16.14 μ) were on par with Arun Gold. The genotypes KR x LR (24.08 μ) and PR x DT (2) (25.18 μ) were on par with Lady Jane. Pollen shape ranged from round to oval and majority of the genotypes had round pollen.

4.1.1.3 Qualitative characters

4.1.1.3.1 Colour of young leaf and petiole

The colour of young leaf showed a range from brown to reddish brown to greenish brown to green to light green. The colour of petiole also varied from brown to reddish brown to greenish brown to green.

4.1.1.3.2 Spathe colour

The colour of the spathe showed variation like deep maroon, maroon, dark red, medium red, red, dark orange, orange, light orange, pink, white, green, violet, brown and some spathe with double colours (obaki).

4.1.1.3.3 Spathe texture

Spathe texture showed wide variation among the 40 genotypes studied, from thick smooth glossy to thick medium blistered glossy to medium thick medium blistered glossy to medium thick slightly blistered glossy to thick slightly blistered glossy to medium thick slightly blistered nonglossy to thin slightly blistered glossy to medium thick slightly blistered nonglossy spathes.

4.1.1.3.4 Candle colour

The candle colour showed variations like pink, light yellow, yellow, maroon, yellowish white, creamish white and greenish yellow.

4.1.1.3.5 Type of Inflorescence axis

Type of Inflorescence axis showed variations like long thick straight, long thin straight, long thick curved, long thin curved, medium thick straight, medium

Table 3c. Qualitative character differentiation in 40 genotypes of *A. andreanum*

Genotype	Petiole	Young leaf	Spathe colour	Spathe texture	Spadix colour	Type of inflorescence axis	Pollen shape
Acropolis white	Green	Green	white	Thick smooth glossy	Yellowish white	Long Thick Straight	Round
Carrie	Greenish brown	Greenish brown	Red	Thick medium blistered glossy	Creamish white	Long Thick Straight	Round
TR x MW	Greenish brown	Reddish brown	Dark red	Thick medium blistered glossy	Pink	Short Thick curved	Round
PR x DT (1)	Brown	Brown	Red	Thick smooth glossy	Light pink	Long thin Straight	Round
Dragon Tongue	Green	Reddish brown	Red	Thin smooth glossy	Light pink & yellowish	Long Thick curved	Oval
PR x OG	Brown	Reddish brown	Orange	Thick slightly blistered non glossy	Yellowish white	Long Thick Straight	Round
KR x LR	Reddish brown	Greenish brown	Dark red	Medium thick smooth glossy	Creamish white	Long Thick Straight	Round
Liver Red	Reddish brown	Reddish brown	Deep maroon	Thick medium blistered glossy	Light pink	Long Thick Straight	Round
Fla Red	Green	Greenish brown	Red	Thick medium blistered glossy	Yellowish white	Long Thick curved	Oval
OG x DT	Green	Green	Light orange	Thick medium blistered glossy	Yellowish white	Long thin curved	Round
PR x DT(2)	Greenish brown	Green	Dark red	Thick smooth glossy	Pink	Long Thick curved	Round
PR x FR	Green	Brown	Medium red	Thick slightly blistered glossy	Yellowish white	Long thin curved	Round
PR x LR	Green	Green	Maroon	Thick medium blistered glossy	Pink	Medium thick curved	Round
NO x DT	Green	Brown	Dark red	Medium thick smooth glossy	Light pink	Medium thin curved	Round
Orange Glory	Green	Brown	Orange	Thick slightly blistered nonglossy	Greenish yellow & white	Short thin Straight	Oval
W x LJ	Green	Brown	Pinkish white	Medium thick smooth nonglossy	Pink	Short thin Straight	Round
Pompon Red	Green	Green	Red	Thick slightly blistered glossy	Yellow	Long Thick Straight	Round
Kalimpong Orange	Greenish brown	Greenish brown	Light orange	Thick slightly blistered glossy	Yellowish pink	Medium Thick Straight	Round
Lady Jane	Green	Light green	Pink	Thick smooth glossy	White	Long Thick Straight	Oval
LR x PR	Greenish brown	Brown	Maroon	Thick slightly blistered glossy	Pink	Short thin Straight	Round
Agnihotri	Green	Greenish brown	Red	Thick medium blistered glossy	Yellowish white	Medium thin curved	Round
Lucia pink	Green	Brown	Pink	Thick medium blistered glossy	Pink	Short Thick Straight	Round

Table 3c Continued

Genotype	Petiole	Young leaf	Spathe colour	Spathe texture	Spadix colour	Type of inflorescence axis	Pollen shape
Nitta Orange	Greenish brown	Greenish brown	Orange	Medium thickmedium blistered glossy	Yellowish white	Medium thin curved	Round
Gold Spark	Green	Green	Light orange	Thick slightly blistered glossy	Yellowish white	Short Thick Straight	Round
Chekas	Greenish brown	Greenish brown	Maroon	Medium thick smooth glossy	Yellowish green	Short Thick Straight	Round
Vezuvious Red	Green	Greenish brown	Red	Thick slightly blistered glossy	Cream	Short Thick Straight	Oval
Boroque	Green	Green	Brownish green	Medium thick medium blistered nonglossy	greenish white	Short Thick Straight	Round
Arun Gold	Green	Brown	Red	Thick slightly blistered nonglossy	Yellow	Long thin curved	Round
Geisha white	Green	Greenish brown	White	Thin smooth glossy	Yellowish white	Long thin curved	Round
Chocos	Green	Green	Brown	Medium thick medium blistered glossy	Yellowish green	Medium thin curved	Round
Hawaiian orange	Green	Greenish brown	Dark orange	Medium thick medium blistered nonglossy	Yellowish white	Long thin curved	Round
Esmeralda	Green	Green	Green	Medium thickdeeply blisterd glossy	Green	Short Thick Straight	Round
Ceasor violet	Greenish brown	Brown	Violet	Thick slightly blistered glossy	Dark pink	Short Thick curved	Round
Rembolina (Pink and Green)	Greenish brown	Greenish brown	Greenish pink	Thick slightly blistered glossy	Creamish yelow	Short Thick curved	Oval
Corolix (Red and Green)	Green	Brown	Greenish red	Thick slightly blistered glossy	Greenish yellow	Short thin curved	Oval
Grace (white)	Green	Green	Greenish white	Medium thicksmooth glossy	Greenish white	Short thin curved	Oval
Diva pink	Greenish brown	Greenish brown	Pink	Thick medium blistered nonglossy	Yellowish white	Medium Thick Straight	Oval
Elan red	Green	Green	Red	Medium thickslightly blistered glossy	Greenish white	Medium Thick Straight	Round
Flirt	Greenish brown	Greenish brown	Dark Red	Thick smooth Glossy	Yellowish white	Medium thin curved	Round
Jewel	Greenish brown	Brown	Dark Red	Thick slightly blistered Glossy	Light pink	Medium thin Straight	Round

thick curved, medium thin curved, short thick straight, short thin straight, short thick curved and short thin curved.

4.1.2 ESTIMATION OF VARIABILITY COMPONENTS

The genotypic and environmental components of phenotypic variance are presented in Table. 4, along with the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), which is the relative measure of variation used for comparison among characters measured in different units.

Maximum phenotypic (91.86 per cent) and genotypic (91.70 per cent) coefficient of variation were observed for anthocyanin content followed by pollen fertility (GCV 54.19 per cent and PCV 55.62 per cent), leaf size/leaf area (GCV 37.23 per cent and PCV 39.57 per cent), spathe size (GCV 33.34 per cent and PCV 36.65 per cent) and spadix length (GCV 27.05 per cent and PCV 29.02 per cent).

The minimum PCV and GCV were recorded by the character days from emergence to maturity of leaves as 7.92 per cent for GCV and 9.62 per cent for PCV. Days from emergence to maturity of inflorescence and number of leaves/ spadices per plant also registered a low value of 8.11 per cent and 10.00 per cent, 11.16 per cent and 13.37 per cent at both genotypic and phenotypic levels respectively.

The characters, days to initiation of female phase, duration of interphase, duration of male phase, number of leaves per plant, spathe size and plant height showed maximum differences between GCV and PCV which indicates that the influence of environment on these characters is considerable. But the low differences between GCV and PCV for the characters total anthocyanin content, pollen size, life of spadix and pollen fertility pointed out that the variation observed in these characters are mainly due to genetic reasons and environmental influence on these characters was less.

Table 4 Components of total variance for different characters in *Anthurium andreanum*

Sl. No.	Characters	σ^2_p	σ^2_g	σ^2_e	PCV (per cent)	GCV (per cent)
1	Plant height (cm)	49.24	37.26	11.97	24.61	21.41
2	Leaf size/leaf area (cm^2)	5076.09	4494.77	581.32	39.57	37.23
3	Internodal length (cm)	0.06	0.05	0.01	16.04	14.29
4	Number of leaves per plant	0.64	0.36	0.28	13.37	10.00
5	Days from emergence to maturity of leaves	9.36	6.34	3.02	9.62	7.92
6	Days from emergence to maturity of inflorescence	9.62	5.08	4.54	11.16	8.10
7	Spathe size (cm^2)	704.67	583.09	121.59	36.65	33.34
8	Total Anthocyanin content (mg/g)	11495.89	11455.36	40.53	91.86	91.70
9	Spadix length (cm)	2.40	2.09	0.31	29.02	27.05
10	Inclination of candle with the spathe (degrees)	122.52	99.03	23.49	21.57	19.39
11	Number of flowers/Spadix	9654.29	8522.02	1132.27	28.56	26.83
12	Life of spadix (days)	190.20	164.61	25.59	19.06	17.73
13	Days to initiation of female phase	3.46	2.50	0.96	28.48	24.19
14	Duration of interphase	2.80	2.05	0.74	26.86	23.01
15	Duration of male phase	4.83	3.75	1.07	28.88	25.47
16	Pollen fertility (per cent)	108.67	103.14	5.53	55.62	54.19
17	Pollen size (μ)	7.00	5.82	1.18	14.20	12.94

σ^2_p -Phenotypic variance σ^2_g -Genotypic variance σ^2_e -Environmental variance

PCV -Phenotypic coefficient of variation GCV -Genotypic coefficient of variation

4.1.3 Heritability and Genetic Advance

The heritability and genetic advance estimates of the various characters are given in Table. 5

Allard (1960) classified heritability as low low (less than 30 per cent), medium (30-60 per cent) and high (above 60 per cent). According to this classification in the present study plant height, leaf size/leaf area, internodal length, days from emergence to maturity of leaves, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size had high heritability estimates. Number of leaves/ spadices per plant and days from emergence to maturity of inflorescence had moderate heritability.

From the Table. 5 it was found that highest heritability was recorded for the character total anthocyanin content (99.65 per cent) followed by pollen fertility (94.92 per cent), leaf size/leaf area (88.55 per cent), number of flowers per spadix (88.27 per cent), spadix length (86.89 per cent). Days from emergence to maturity of inflorescence showed the least value of 52.76 per cent for heritability.

Genetic advance as percentage of mean is independent of the unit of measurement and hence is used for comparison of characters. Maximum genetic advance was obtained for anthocyanin content (188.57 per cent) followed by pollen fertility (108.76 per cent), leaf size/leaf area (72.18 per cent), spathe size (62.48 per cent). The least genetic advance was obtained for days from emergence to maturity of inflorescence (12.13 per cent).

Robinson *et al.* (1949) categorized genetic advance into low (<20 per cent) and high (>20 per cent). According to this classification plant height, leaf size/leaf area, internodal length, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility, and pollen size had high genetic advance, while number of leaves/

Table 5 Heritability and genetic advance of seventeen characters in *Anthurium andreanum*

Sl. No.	Characters	Heritability (per cent)	Genetic advance (5 per cent)	Genetic advance as percentage of mean
1	Plant height (cm)	75.68	10.94	38.37
2	Leaf size/leaf area (cm^2)	88.55	129.96	72.18
3	Internodal length (cm)	79.41	0.41	26.24
4	Number of leaves/spadices per plant	55.87	0.92	15.39
5	Days from emergence to maturity of leaves	67.71	4.27	13.42
6	Days from emergence to maturity of inflorescence	52.76	3.37	12.13
7	Spathe size (cm^2)	82.75	45.25	62.48
8	Total Anthocyanin content (mg/g)	99.65	220.09	188.57
9	Spadix length (cm)	86.89	2.77	51.93
10	Inclination of candle with the spathe (degrees)	80.83	18.43	35.91
11	Number of flowers/Spadix	88.27	178.67	51.93
12	Life of spadix (days)	86.54	24.59	34.00
13	Days to initiation of female phase	72.13	2.76	42.33
14	Duration of interphase	73.41	2.53	40.61
15	Duration of male phase	77.79	3.52	46.27
16	Pollen fertility (per cent)	94.92	20.38	108.76
17	Pollen size (μ)	83.12	4.53	24.31

spadices per plant, days from emergence to maturity of leaves and days from emergence to maturity of inflorescence had low genetic advance.

High heritability coupled with high genetic advance was observed for plant height, leaf size/leaf area, internodal length, spathe size, anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size.

4.1.4 Correlation Studies

The results of phenotypic, genotypic and environmental correlations among the various characters were estimated and the results of the correlation analysis are presented in Table 6 (a, b and c).

4.1.4.1 Phenotypic correlation

Plant height was found to have significant positive correlation with leaf size/leaf area (0.6974), internodal length (0.4187), total Anthocyanin content (0.4355), spadix length (0.5188), number of flowers per spadix (0.5912) and life of spadix (0.3859). However, no significant correlation was observed for plant height with other characters.

Leaf size/leaf area showed significant positive correlation with plant height (0.6974), internodal length (0.6090), total Anthocyanin content (0.4322), spadix length (0.7225), number of flowers per spadix (0.7988), life of spadix (0.5705), pollen fertility (0.3719) and pollen size (0.4722). For all other characters Leaf size/leaf area was not significantly correlated.

Internodal length showed significant positive correlation with plant height (0.4187), leaf size/leaf area (0.6090), Spathe size (0.5114),spadix length (0.5190), number of flowers per spadix (0.5730) and life of spadix (0.3665). All other characters had no significant correlation.

Days from emergence to maturity of inflorescence was found to have significant positive correlation with life of spadix (0.3858) and pollen fertility (0.3719).

Table 6a Phenotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	1.0000	0.6974**	0.4187**	0.2394	0.0128	0.1592	0.1304	0.4355**	0.5188**	-0.1755	0.5912**	0.3859*	-0.2575	0.1843	-0.0687	0.1903	0.3026
X_2		1.0000	0.6090**	0.0276	0.0066	0.1782	0.2918	0.4322**	0.7225**	-0.0358	0.7988**	0.5705**	-0.2821	0.1933	0.1396	0.3719*	0.4722**
X_3			1.0000	0.0948	-0.2905	0.0218	0.5114**	0.1222	0.5190**	-0.1090	0.5730**	0.3665*	-0.2494	0.0105	0.0719	0.0788	0.2572
X_4				1.0000	-0.0462	-0.0387	-0.1140	-0.0691	0.0317	-0.2513	-0.0541	-0.1325	0.0972	-0.0892	-0.3240*	-0.1763	-0.0587
X_5					1.0000	0.0627	0.2534	0.1489	-0.1287	0.0388	-0.1139	0.0236	-0.0154	0.0605	0.0985	0.0051	0.0836
X_6						1.0000	-0.0722	0.2976	0.1534	-0.1214	0.1436	0.3858*	-0.0708	0.1930	0.0587	0.3719*	0.0961
X_7							1.0000	-0.0589	0.4306**	0.1555	0.3515*	0.2641	-0.0650	0.0138	0.0706	-0.0281	0.1556
X_8								1.0000	0.1764	-0.0267	0.3105	0.3909*	-0.1864	0.3494*	0.1331	0.1878	0.3419*
X_9									1.0000	-0.0556	0.7905**	0.4503**	-0.3662*	0.1909	0.0608	0.4119**	0.5040**
X_{10}										1.0000	-0.0834	-0.0562	-0.0410	-0.0368	0.0707	-0.0313	-0.0820
X_{11}											1.0000	0.4973**	-0.2287	0.1668	0.0467	0.3196**	0.5323**
X_{12}												1.0000	-0.2037	0.1988	0.2529	0.4307**	0.2317
X_{13}													1.0000	0.1089	-0.1569	-0.3673*	-0.1045
X_{14}														1.0000	0.1674	0.0746	0.2316
X_{15}															1.0000	0.0484	-0.0203
X_{16}																1.0000	0.2858
X_{17}																	1.0000

*Significant at 5 percent level **Significant at 1 per cent level

X_1 Plant height (cm)
X_2 Leaf size/leaf area (cm^2)
X_3 Internodal length (cm)
X_4 Number of leaves per plant
X_5 Days from emergence to maturity of leaves
X_6 Days from emergence to maturity of inflorescence
X_7 Spathe size (cm^2)
X_8 Total Anthocyanin content (mg/g)
X_9 Spadix length (cm)
X_{10} Inclination of candle with the spathe (degrees)
X_{11} Number of flowers/Spadix
X_{12} Life of spadix (days)
X_{13} Days to initiation of female phase
X_{14} Duration of interphase
X_{15} Duration of male phase
X_{16} Pollen fertility (per cent)
X_{17} Pollen size (μ)

Table 6b Genotypic correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	1.0000	0.8242**	0.5716**	0.2812	-0.0330	0.2417	0.1815	0.5000**	0.6432**	-0.1831	0.7621**	0.4179**	-0.3381*	0.1972	-0.1006	0.2021	0.3725*
X_2		1.0000	0.7241**	0.0517	0.0002	0.3539*	0.3371*	0.4627**	0.8303**	-0.0576	0.8935**	0.6445**	-0.3522*	0.2511	0.1449	0.3868*	0.5294**
X_3			1.0000	0.2564	-0.3555*	0.0617	0.6267**	0.1400	0.6602**	-0.1243	0.6689**	0.4752**	-0.3025	0.0627	0.0723	0.0887	0.3395*
X_4				1.0000	-0.0648	-0.6440**	-0.0305	-0.0939	0.0542	-0.3016	-0.0315	-0.2156	0.0802	-0.1643	-0.4885**	-0.2440	-0.0373
X_5					1.0000	0.0982	-0.4063**	0.1787	-0.1639	0.0723	-0.1267	0.0495	-0.0519	0.1077	0.1625	-0.0304	0.0976
X_6						1.0000	-0.0247	0.4055**	0.2131	-0.0983	0.2305	0.5842**	-0.0869	0.3917*	0.1162	0.5665**	0.1893
X_7							1.0000	-0.0664	0.5142**	0.1991	0.4189**	0.3073	-0.0815	-0.0129	0.0689	-0.0610	0.1415
X_8								1.0000	0.1870	-0.0283	0.3318*	0.4196**	-0.2158	0.4109**	0.1556	0.1905	0.3767*
X_9									1.0000	-0.0697	0.9011**	0.5185**	-0.4208**	0.2305	0.1050	0.4520**	0.6006**
X_{10}										1.0000	-0.0946	-0.0701	-0.0637	-0.0471	0.0679	-0.0462	-0.1290
X_{11}											1.0000	0.5834**	-0.2765	0.2138	0.0552	0.3584*	0.6310**
X_{12}												1.0000	-0.2950	0.1866	0.2692	0.4646**	0.2814
X_{13}													1.0000	0.0955	-0.2613	-0.4455**	-0.1893
X_{14}														1.0000	0.1783	0.0951	0.2852
X_{15}															1.0000	0.0714	-0.0157
X_{16}																1.0000	0.3171*
X_{17}																	1.0000

*Significant at 5 percent level **Significant at 1 per cent level

X_1 Plant height (cm)
X_2 Leaf size/leaf area (cm^2)
X_3 Internodal length (cm)
X_4 Number of leaves per plant
X_5 Days from emergence to maturity of leaves
X_6 Days from emergence to maturity of inflorescence
X_7 Spathe size (cm^2)
X_8 Total Anthocyanin content (mg/g)
X_9 Spadix length (cm)
X_{10} Inclination of candle with the spathe (degrees)
X_{11} Number of flowers/Spadix
X_{12} Life of spadix (days)
X_{13} Days to initiation of female phase
X_{14} Duration of interphase
X_{15} Duration of male phase
X_{16} Pollen fertility (per cent)
X_{17} Pollen size (μ)

Table 6c Environmental correlation coefficients among seventeen characters in *Anthurium andreanum*

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	1.0000	0.1359	-0.1090	0.1726	0.1300	0.0192	-0.0643	0.0448	-0.0155	-0.1493	-0.1874	0.2636	-0.0293	0.1466	0.0363	0.1714	0.0352
X_2		1.0000	0.0120	-0.0390	0.0343	-0.2737	0.0230	-0.1234	-0.0472	0.0872	0.0763	0.0512	-0.0036	-0.0522	0.1212	0.2262	0.1296
X_3			1.0000	-0.2521	-0.1157	-0.0581	0.0180	-0.0891	-0.1790	-0.0472	0.0838	-0.1644	-0.0853	-0.1597	0.0706	0.0173	-0.1000
X_4				1.0000	-0.1690	-0.0082	-0.3380*	0.0234	-0.0250	-0.1672	-0.1406	0.0712	0.1318	0.0466	-0.0064	0.0091	-0.1217
X_5					1.0000	0.0103	0.2147	0.0647	-0.0147	-0.0591	-0.0821	-0.0685	0.0695	-0.0527	-0.0724	0.2303	0.0444
X_6						1.0000	-0.1957	0.0891	0.0367	-0.1899	-0.0584	-0.0357	-0.0475	-0.1432	-0.0486	-0.1868	-0.1036
X_7							1.0000	0.0569	-0.0359	-0.0405	-0.0454	0.0268	-0.0094	0.1115	0.0781	0.2771	0.2244
X_8								1.0000	0.1096	-0.0483	-0.0307	0.0556	-0.1115	-0.0655	-0.1368	0.1890	-0.0363
X_9									1.0000	0.0178	0.0115	0.0052	-0.1729	0.0367	-0.1493	0.0182	-0.0431
X_{10}										1.0000	-0.0232	0.0152	0.0332	-0.0025	0.0816	0.0927	0.1319
X_{11}											1.0000	-0.1005	-0.0447	-0.0298	0.0061	-0.1104	-0.0580
X_{12}												1.0000	0.1516	0.2649	0.1852	0.1167	-0.0460
X_{13}													1.0000	0.1448	0.1563	0.0113	0.1937
X_{14}														1.0000	0.1343	-0.0410	0.0419
X_{15}															1.0000	-0.1224	-0.0397
X_{16}																1.0000	0.0446
X_{17}																	1.0000

*Significant at 5 per cent level **Significant at 1 per cent level

X_1 Plant height (cm)
X_2 Leaf size/leaf area (cm^2)
X_3 Internodal length (cm)
X_4 Number of leaves per plant
X_5 Days from emergence to maturity of leaves
X_6 Days from emergence to maturity of inflorescence
X_7 Spathe size (cm^2)
X_8 Total Anthocyanin content (mg/g)
X_9 Spadix length (cm)
X_{10} Inclination of candle with the spathe (degrees)
X_{11} Number of flowers/Spadix
X_{12} Life of spadix (days)
X_{13} Days to initiation of female phase
X_{14} Duration of interphase
X_{15} Duration of male phase
X_{16} Pollen fertility (per cent)
X_{17} Pollen size (μ)

Spathe size showed significant positive correlation with internodal length (0.5114), spadix length (0.4306) and number of flowers per spadix (0.3515).

Total Anthocyanin content showed significant positive correlation with plant height (0.4355), leaf size/leaf area (0.4322), life of spadix (0.3903), days to interphase (0.3494) and pollen size (0.3419).

Spadix length showed significant positive correlation with plant height (0.5188), leaf size/leaf area (0.7225), internodal length (0.5190), spathe size (0.4306), number of flowers per spadix (0.7905), life of spadix (0.4503), pollen fertility (0.4119) and pollen size (0.5040) while significant negative correlation was observed for days to initiation of female phase (-0.3662).

Number of flowers per spadix was found to have significant positive correlation with plant height (0.5912), leaf size/leaf area (0.7988), internodal length (0.573), spathe size (0.3515), spadix length (0.7905), life of spadix (0.4973) pollen fertility (0.3196) and pollen size (0.5323).

Life of spadix showed significant positive correlation with plant height (0.3859), leaf size/leaf area (0.5705), internodal length (0.3665), days from emergence to maturity of inflorescence (0.3858), total Anthocyanin content (0.3909), spadix length (0.4503), number of flowers per spadix (0.4973) and pollen fertility (0.4307).

Days to initiation of female phase was found to have significant negative correlation with spadix length (-0.3662) and pollen fertility (-0.3673). Days to interphase showed significant positive correlation with total Anthocyanin content (0.3494). Duration of male phase recorded a significant negative correlation with number of leaves/ spadices per plant (-0.3240).

Pollen fertility showed significant positive correlation with leaf size/leaf area and days from emergence to maturity of inflorescence (0.3719), spadix length (0.4119), number of flowers per spadix (0.3196), life of spadix (0.4307) while it showed significant negative correlation with days to initiation of female phase (-0.3673).

Pollen size was found to have significant positive correlation with leaf size/leaf area (0.4722), total Anthocyanin content (0.3419), spadix length (0.5040) and number of flowers per spadix (0.5323).

Number of leaves/spadices per plant, days from emergence to maturity of leaves and inclination of candle with the spathe had no significant correlation with other characters.

4.1.4.2 Genotypic correlation

Genotypic correlation values are higher than the phenotypic values in all most all cases. Most of the characters had positive correlation with each other.

Plant height showed positive and significant genotypic correlation with leaf size/leaf area (0.8242), internodal length (0.5716), total Anthocyanin content (0.5000), Spadix length (0.6432), number of flowers per spadix (0.7621), life of spadix (0.4179) and pollen size (0.3725) while it showed significant negative correlation with days to initiation of female phase (-0.3381).

Leaf size/leaf area showed significant positive correlation with plant height (0.8242), internodal length (0.7241), days from emergence to maturity of inflorescence (0.3539), spathe size (0.3371), total Anthocyanin content (0.4627), Spadix length (0.8303), number of flowers per spadix (0.8935), life of spadix (0.6445), pollen fertility (0.3868) and pollen size (0.5294) while it showed significant negative correlation with days to initiation of female phase (-0.3522),

Internodal length showed significant positive correlation with plant height (0.5716), leaf size/leaf area (0.7241), spathe size (0.6267), spadix length (0.6602), number of flowers per spadix (0.6689), life of spadix (0.4752), pollen size (0.3395) while it showed significant negative correlation with days from emergence to maturity of leaves(-0.3555).

Number of leaves/spadices per plant was found to have significant negative correlation with duration of male phase (-0.4885) and days from emergence to maturity of inflorescence (-0.6440). Days from emergence to

maturity of leaves was found to have significant negative correlation with internodal length (-0.3555) and spathe size (-0.4063).

Days from emergence to maturity of inflorescence exhibited significant positive correlation with leaf size/leaf area (0.3539), total anthocyanin content (0.4055), life of spadix (0.5842), days to interphase (0.3917) and pollen fertility (0.5665) and it showed significant negative correlation with number of leaves/ spadices per plant (-0.6440)

Spathe size showed significant positive correlation with leaf size/leaf area (0.3371), internodal length (0.6267), Spadix length (0.5142) and number of flowers per spadix (0.4189) while it showed significant negative correlation with days from emergence to maturity of leaves (-0.4063).

Total anthocyanin content showed significant positive correlation with plant height (0.5000), leaf size/leaf area (0.4627), days from emergence to maturity of inflorescence (0.4055), number of flowers per spadix (0.3318), life of spadix (0.4196), days to interphase (0.4109) and pollen size (0.3767).

Spadix length showed significant positive correlation with plant height (0.6432), leaf size/leaf area (0.8303), internodal length (0.6602), spathe size (0.5142), number of flowers per spadix (0.9011), life of spadix (0.5185) and pollen size (0.6006) while it showed significant negative correlation with days to initiation of female phase (-0.4208).

Number of flowers per spadix was found to have significant positive correlation with plant height (0.7621), leaf size/leaf area (0.8935), internodal length (0.6689), spathe size (0.4189), total Anthocyanin content (0.3318), spadix length (0.9010), life of spadix (0.5834), pollen fertility (0.3584) and pollen size (0.6310).

Life of spadix was found to have significant positive correlation with plant height (0.4179), leaf size/leaf area (0.6445), internodal length (0.4752), days from emergence to maturity of inflorescence (0.5842), total anthocyanin content

(0.4196), Spadix length (0.5185), number of flowers per spadix (0.5834) and pollen fertility (0.4646).

Days to initiation of female phase exhibited significant negative correlation with plant height (-0.3381), leaf size/leaf area (-0.3522), Spadix length (-0.4208) and pollen fertility (-0.4455).

Days to interphase was found to have significant positive correlation with days from emergence to maturity of inflorescence (0.3917) and total anthocyanin content (0.4109). Duration of male phase showed significant negative correlation with number of leaves/spadices per plant (-0.4885).

Pollen fertility showed significant positive correlation with leaf size/leaf area (0.3868), days from emergence to maturity of inflorescence (0.5665), spadix length (0.4520) number of flowers per spadix (0.3584), life of spadix (0.4646) while showed significant negative correlation with days to initiation of female phase (-0.4455).

Pollen size was found to have significant positive correlation with plant height (0.3725), leaf size/leaf area (0.5294), internodal length (0.3395), total anthocyanin content (0.3767), spadix length (0.6006), number of flowers per spadix 90.6310) and pollen fertility (0.3171).

4.1.4.3 Environmental correlation

Number of leaves/spadices per plant showed significant negative correlation with spathe size (-0.3380). Environmental correlation among other characters was not significant.

4.1.5 Path analysis:

Number of flowers per spadix was taken as a dependent character and path analysis was worked out. Plant height, leaf size/leaf area, internodal length, days from emergence to maturity of inflorescence, spathe size, anthocyanin content, spadix length, life of spadix, days to initiation of female phase, days to inter phase, pollen fertility and pollen size were the characters used for the study.

The analysis revealed the direct and indirect effects of various characters on yield as presented in the Table. 7

The highest direct effect was observed for spadix length (0.5212) followed by plant height (0.2489), leaf size (0.1940), life of spadix (0.1786), days to initiation of female phase (0.1650), pollen size (0.1488) and pollen fertility (0.0114), spathe size (-0.0075), anthocyanin content (-0.0097), internodal length (-0.0286), days to inter phase (-0.0481) and days from emergence to maturity of inflorescence (-0.1097).

Plant height, leaf size/leaf area, spadix length, life of spadix, days to initiation of female phase, pollen fertility and pollen size had positive direct effect while internodal length, days from emergence to maturity of inflorescence, spathe size, anthocyanin content and days to interphase had negative direct effect.

The correlation between plant height and flowers per spadix was 0.7621 and its direct effect was positive and high (0.2489). Indirect effect via spadix length (0.3353) and leaf size (0.1599) contributed towards this correlation.

The correlation between leaf size/leaf area and flowers per spadix was found to be is positive (0.8935) but its direct effect was positive (0.1940). Most of the indirect effects were negligible. The high indirect effect via spadix length (0.4328) and plant height (0.2052) contributed towards genetic correlation.

The correlation between internodal length and flowers per spadix was 0.6689 and its direct effect was negative and very low/ negligible (-0.0286). Most of the indirect effects were negligible. The high indirect effect via spadix length (0.3441) was recorded.

The correlation between days from emergence to maturity of inflorescence and flowers per spadix was 0.2305 and its direct effect was negative and very low/ negligible (-0.1097). Most of the indirect effects were also negligible. The indirect effect via spadix length (0.1111) and life of spadix (0.1043) majorly contributed towards correlation.

Table7 Direct and indirect effects of component characters on number of flowers per spadix in *Anthurium andreanum*

Characters		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	Genotypic correlation with number of flowers per spadix
Plant height (cm)	(X_1)	**0.2489**	0.1599	-0.0164	-0.0265	-0.0014	-0.0049	0.3353	0.0746	-0.0558	-0.0095	0.0023	0.0554	0.7621
Leaf size/leaf area (cm^2)	(X_2)	0.2052	**0.1940**	-0.0207	-0.0388	-0.0025	-0.0045	0.4328	0.1151	-0.0581	-0.0121	0.0044	0.0788	0.8935
Internodal length (cm)	(X_3)	0.1423	0.1405	**-0.0286**	-0.0068	-0.0047	-0.0014	0.3441	0.0849	-0.0499	-0.0030	0.0010	0.0505	0.6689
Days from emergence to maturity of inflorescence	(X_4)	0.0602	0.0687	-0.0018	**-0.1097**	0.0002	-0.0039	0.1111	0.1043	-0.0143	-0.0188	0.0065	0.0282	0.2305
Spathe size (cm^2)	(X_5)	0.0452	0.0654	-0.0179	0.0027	**-0.0075**	0.0006	0.2680	0.0549	-0.0134	0.0006	-0.0007	0.0211	0.4189
Total Anthocyanin content (mg/g)	(X_6)	0.1245	0.0898	-0.0040	-0.0445	0.0005	**-0.0097**	0.0975	0.0749	-0.0356	-0.0198	0.0022	0.0560	0.3318
Spadix length (cm)	(X_7)	0.1601	0.1611	-0.0189	-0.0234	-0.0039	-0.0018	**0.5212**	0.0926	-0.0694	-0.0111	0.0052	0.0894	0.9011
Life of spadix (days)	(X_8)	0.1040	0.1251	-0.0136	-0.0641	-0.0023	-0.0041	0.2703	**0.1786**	-0.0487	-0.0090	0.0053	0.0419	0.5834
Days to initiation of female phase	(X_9)	-0.0842	-0.0683	0.0087	0.0095	0.0006	0.0021	-0.2193	-0.0527	**0.1650**	-0.0046	-0.0051	-0.0282	-0.2765
Duration of interphase	(X_{10})	0.0491	0.0487	-0.0018	-0.0430	0.0001	-0.0040	0.1201	0.0333	0.0158	**-0.0481**	0.0011	0.0424	0.2138
Pollen fertility (per cent)	(X_{11})	0.0503	0.0751	-0.0025	-0.0621	0.0005	-0.0019	0.2356	0.0830	-0.0735	-0.0046	**0.0114**	0.0472	0.3584
Pollen size (μ)	(X_{12})	0.0927	0.1027	-0.0097	-0.0208	-0.0011	-0.0037	0.3131	0.0503	-0.0312	-0.0137	0.0036	**0.1488**	0.6310

Residual effect: 0.2679

The correlation between spathe size and flowers per spadix was 0.4189 and its direct effect was negative and very low/ negligible (-0.0075). The high indirect effect via spadix length (0.2680) and indirect effects via other characters were negligible.

The correlation between anthocyanin content and flowers per spadix was 0.3318 and its direct effect was negative and very low/ negligible (-0.0097). The indirect effect via plant height (0.1245) and spadix length (0.0975) majorly contributed towards correlation and indirect effects via other characters were negligible.

The correlation between spadix length and flowers per spadix was 0.9011 and its direct effect was positive and high (0.5212). Most of the indirect effects were negligible.

The correlation between life of spadix and flowers per spadix was 0.5834 and its direct effect was positive (0.1786). The indirect effect via spadix length (0.2703), plant height (0.1040) and leaf size/leaf area (0.1251) majorly contributed towards correlation.

The correlation between days to initiation of female phase and flowers per spadix was negative (-0.2765) and its direct effect was positive (0.1650). The indirect effect via spadix length (-0.2193) majorly contributed towards total correlation.

The correlation between days to inter phase and flowers per spadix was 0.2138 and its direct effect was negative and negligible (-0.0481). Most of the indirect effects were negligible. The indirect effect via spadix length (0.1201) majorly contributed towards correlation.

The correlation between pollen fertility and flowers per spadix was 0.3584 and its direct effect was positive (0.1140). Most of the indirect effects were negligible. The high indirect effect via spadix length (0.2356) was recorded.

Table7 Direct and indirect effects of component characters on number of flowers per spadix in *Anthurium andreanum*

Characters		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	Genotypic correlation with number of flowers per spadix
Plant height (cm)	(X_1)	**0.2489**	0.1599	-0.0164	-0.0265	-0.0014	-0.0049	0.3353	0.0746	-0.0558	-0.0095	0.0023	0.0554	0.7621
Leaf size/leaf area (cm^2)	(X_2)	0.2052	**0.1940**	-0.0207	-0.0388	-0.0025	-0.0045	0.4328	0.1151	-0.0581	-0.0121	0.0044	0.0788	0.8935
Internodal length (cm)	(X_3)	0.1423	0.1405	**-0.0286**	-0.0068	-0.0047	-0.0014	0.3441	0.0849	-0.0499	-0.0030	0.0010	0.0505	0.6689
Days from emergence to maturity of inflorescence	(X_4)	0.0602	0.0687	-0.0018	**-0.1097**	0.0002	-0.0039	0.1111	0.1043	-0.0143	-0.0188	0.0065	0.0282	0.2305
Spathe size (cm^2)	(X_5)	0.0452	0.0654	-0.0179	0.0027	**-0.0075**	0.0006	0.2680	0.0549	-0.0134	0.0006	-0.0007	0.0211	0.4189
Total Anthocyanin content (mg/g)	(X_6)	0.1245	0.0898	-0.0040	-0.0445	0.0005	**-0.0097**	0.0975	0.0749	-0.0356	-0.0198	0.0022	0.0560	0.3318
Spadix length (cm)	(X_7)	0.1601	0.1611	-0.0189	-0.0234	-0.0039	-0.0018	**0.5212**	0.0926	-0.0694	-0.0111	0.0052	0.0894	0.9011
Life of spadix (days)	(X_8)	0.1040	0.1251	-0.0136	-0.0641	-0.0023	-0.0041	0.2703	**0.1786**	-0.0487	-0.0090	0.0053	0.0419	0.5834
Days to initiation of female phase	(X_9)	-0.0842	-0.0683	0.0087	0.0095	0.0006	0.0021	-0.2193	-0.0527	**0.1650**	-0.0046	-0.0051	-0.0282	-0.2765
Duration of interphase	(X_{10})	0.0491	0.0487	-0.0018	-0.0430	0.0001	-0.0040	0.1201	0.0333	0.0158	**-0.0481**	0.0011	0.0424	0.2138
Pollen fertility (per cent)	(X_{11})	0.0503	0.0751	-0.0025	-0.0621	0.0005	-0.0019	0.2356	0.0830	-0.0735	-0.0046	**0.0114**	0.0472	0.3584
Pollen size (μ)	(X_{12})	0.0927	0.1027	-0.0097	-0.0208	-0.0011	-0.0037	0.3131	0.0503	-0.0312	-0.0137	0.0036	**0.1488**	0.6310

Residual effect: 0.2679

The correlation between Pollen size and flowers per spadix was 0.6310 and its direct effect was positive (0.1488). The high indirect effect via spadix length (0.3131).

The residual value was 0.2679 indicating that about 73 percent of the variation in flowers per spadix was contributed by the characters selected for analysis.

4.1.6 Genetic Divergence Analysis

The 40 genotypes of anthurium were subjected to Mahalanobis D^2 analysis based on the 13 characters viz., plant height, leaf size/leaf area, internodal length, days from emergence to maturity of inflorescence, spathe size, total anthocyanin content, Spadix length, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, pollen fertility and pollen size.

The genotypes were grouped into seven clusters using Tocher's method of clustering. The clustering pattern is presented in Table. 8. The cluster I had the highest number of genotypes (17) followed by cluster II (7), cluster III (5), cluster IV (5) and cluster V (4). Clusters VI and VII had one genotype each. The cluster I had the genotypes Fla Red, W x LJ, Pompon Red, Kalympong Orange, Agnihotri, Lucia pink, Nitta Orange, Gold Spark, Vezuvious Red, Boroque, Chocos, Hawaiian orange, Esmeralda, Rembolina, Corolix, Grace, Diva pink (DV). The genotypes Acropolis white, Carrie, PR x OG, OG x DT, Orange Glory, Lady Jane and Geisha White were included in the cluster II. The cluster III had PR x DT (1), Dragon's Tongue , KR x LR, PR x DT (2) and NO x DT. The genotypes PR x FR, LR x PR, Chekas, Arun Gold and Jewel constituted the cluster IV, cluster V had TR x MW, Ceasor violet, Elan Red and Flirt. The genotypes PR x LR and Liver Red (LR) remained as divergent genotypes that cannot be accommodated in any of the clusters and each remained as a separate cluster.

The average inter and intra cluster distances were estimated based on the total D^2 values. The inter and intra cluster distances (D^2) of the various clusters were worked out and presented in Table 9. The intra cluster distance varied from

0 (Cluster VI and VII) to 191.82 (Cluster II). The inter cluster distances varied from 269.43 (between clusters I and II) to 5863.90 (between Clusters II and VI).

The cluster means for each character is presented in Table. 10. The cluster means were high in cluster VII for characters Plant height, leaf size/leaf area, days from emergence to maturity of inflorescence, spathe size, Spadix length, number of flowers per spadix, life of spadix, days to inter phase and pollen fertility. Cluster VI had high cluster means for days from emergence to maturity of leaves, total anthocyanin content and pollen size. Cluster mean was high for internodal length and days to initiation of female phase in cluster III and duration of male phase in cluster IV. Character contribution towards divergence presented in Table. 11. Among the 13 characters considered life of spadix (51.01 per cent) contributed maximum towards divergence followed by days to initiation of female phase (30.77 per cent). Days to inter phase (3.37 per cent), pollen size (2.97 per cent), internodal length and spathe size (2.70 per cent) and pollen fertility (2.16 per cent).

The cluster I had the greatest distance from Cluster VI followed by Clusters VII, III, IV, V and II. The cluster II was at the greatest distance from Cluster VI followed by VII, III, IV, V and I. The maximum distance of cluster III was from cluster VI followed by II, I, VII, V and IV. The cluster IV was at the maximum distance from VI followed by VII, II, I, III and V. The cluster V had the greatest distance from VI followed by VII, III, II, I and IV. The Cluster VI was at the greatest distance from II followed by I, V, IV, III and VII. The cluster VII was at maximum distance from II followed byI, V, IV, III and VI.

4.1.7 Selection Index

Selection index for the genotypes was computed based on the 13 characters namely, Plant height (X_1), leaf size/leaf area (X_2), internodal length (X_3), days from emergence to maturity of inflorescence (X_4), spathe size(X_5), total anthocyanin content (X_6), Spadix length (X_7), number of flowers per spadix (X_8), life of spadix (X_9), days to initiation of female phase (X_{10}), days to inter

Table 8 Clustering pattern

Sl. No.	Cluster number	Number of genotypes	Genotypes
1	I	17	Fla Red, W x LJ, Pompon Red, Kalympong Orange, Agnihotri, Lucia pink, Nitta Orange, Gold Spark, Vezuvious Red, Boroque, Chocos, Hawaiianian orange, Esmeralda, Rembolina, Corolix, Grace, Diva pink (DV)
2	II	7	Acropolis white, Carrie, PR x OG, OG x DT, Orange Glory, Lady Jane and Geisha White
3	III	5	PR x DT (1), Dragon Tongue, KR x LR, PR x DT (2), NO x DT
4	IV	5	PR x FR, LR x PR, Chekas, Arun Gold, Jewel
5	V	4	TR x MW, Ceasor violet, Elan Red, Flirt.
6	VI	1	PR x LR
7	VII	1	Liver Red

Table 9 Average inter and intra cluster distances (D^2 values)

Cluster	I	II	III	IV	V	VI	VII
I	168.7825	269.4337	1242.3750	597.6770	288.0352	5286.4910	3195.8170
II		191.8200	1419.4670	859.1824	443.3109	5863.8950	3437.9300
III			147.4700	504.3696	612.8741	1712.6640	649.9200
IV				160.2488	282.0555	2716.0000	1354.9150
V					140.6100	3736.2940	2155.0500
VI						0.0000	565.4100
VII							0.0000

Table 10 Cluster means of the various characters

Custer	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
1	25.02	135.94	1.44	5.92	31.72	26.56	69.49	55.39	4.58	53.49	290.71	63.86	7.43	5.97	6.73	16.30	17.72
2	30.02	222.52	1.70	6.11	30.64	29.11	84.81	36.20	6.74	48.58	411.81	81.35	5.75	5.39	8.11	25.47	19.22
3	18.68	120.15	2.05	5.34	22.45	20.55	56.44	34.86	6.11	36.69	237.17	54.07	7.73	7.45	8.95	18.59	17.65
4	28.07	146.94	1.43	5.86	31.81	29.06	57.31	184.55	4.39	50.43	268.40	72.83	5.66	7.02	9.07	19.86	16.94
5	25.45	156.39	1.66	5.81	29.15	26.32	67.01	77.75	5.46	47.30	302.02	68.03	6.64	6.46	8.21	20.06	17.88
6	39.00	253.39	1.57	5.93	34.94	31.22	57.85	482.05	4.81	43.60	414.00	86.92	7.50	6.57	6.33	14.35	21.25
7	43.25	302.38	1.72	6.33	29.83	33.39	93.52	386.23	7.19	55.83	494.67	93.83	6.15	9.18	5.53	42.68	20.08

X_1 Plant height (cm)
X_2 Leaf size/leaf area (cm^2)
X_3 Internodal length (cm)
X_4 Number of leaves per plant
X_5 Days from emergence to maturity of leaves
X_6 Days from emergence to maturity of inflorescence
X_7 Spathe size (cm^2)
X_8 Total Anthocyanin content (mg/g)
X_9 Spadix length (cm)
X_{10} Inclination of candle with the spathe (degrees)
X_{11} Number of flowers/Spadix
X_{12} Life of spadix (days)
X_{13} Days to initiation of female phase
X_{14} Duration of interphase
X_{15} Duration of male phase
X_{16} Pollen fertility (per cent)
X_{17} Pollen size (μ)

Table 11 Character contribution towards divergence

Sl. No.	Character	Contribution (per cent)
1	Plant height (cm)	0.13
2	Leaf size/leaf area (cm^2)	1.62
3	Internodal length (cm)	2.70
4	Days from emergence to maturity of inflorescence	0.001
5	Spathe size (cm^2)	2.70
6	Total Anthocyanin content (mg/g)	0.94
7	Spadix length (cm)	0.81
8	Number of flowers per spadix	0.81
9	Life of spadix (days)	51.01
10	Days to initiation of female phase	30.77
11	Duration of interphase	3.37
12	Pollen fertility (per cent)	2.16
13	Pollen size (μ)	2.97

Table 12 Selection indices arranged in descending order

Sl. No.	genotype	Selection index values
1	Liver Red	1691.88
2	PR x LR	1590.19
3	PR x DT (1)	1563.69
4	PR x DT (2)	1523.05
5	KR x LR	1448.32
6	OG x DT	1347.45
7	Dragon Tongue	1258.17
8	PR x OG	1215.06
9	NO x DT	1214.78
10	PR x FR	1190.50
11	Lady Jane	1181.22
12	Acropolis white	1151.26
13	Fla Red	1137.75
14	Carrie	1110.79
15	Ceasor violet	1089.92
16	TR x MW	1084.73
17	Elan red	1080.10
18	Hawaiian orange	1069.77
19	Geisha white	1046.52
20	Boroque	1044.35
21	Ponpon Red	1042.32
22	Flirt	1016.75
23	Arun Gold	1010.70
24	Chekas	987.42
25	Jewel	970.54
26	LR x PR	961.22
27	Esmelalda	952.70
28	Nitta Orange	911.94
29	Kalimpong Orange	892.63
30	Chocos	891.81
31	Lucia pink	878.02
32	Agnihotri	865.50
33	Vezuvious Red	855.51
34	Orange Glory	839.74
35	Gold Spark	828.40
36	Diva pink	778.07
37	Grace (white)	753.75
38	Corolix (Red and Green)	747.37
39	W x LJ	734.44
40	Rembolina (Pink and Green)	729.30

phase(X_{11}), pollen fertility (X_{12}) and pollen size(X_{13}). The selection index worked out was as follows:

$I = 2.3254X_1 + 0.6532\ X_2 + 68.1412\ X_3 + 3.1948\ X_4 + 0.6121\ X_5 + 1.0605\ X_6 + 22.9186\ X_7 + 0.6538\ X_8 + 1.3208\ X_9 + 4.2266\ X_{10} - 1.4502\ X_{11} + 0.6475\ X_{12} + 2.5312\ X_{13}$

Accordingly selection index values were worked out and presented in the Table. 12 in descending order. Based on the analysis genotype Liver Red attained the maximum selection index value (1691.88) followed by PR x LR (1590.19) and PR x DT (1) (1563.69) and the minimum estimates were recorded for Rembolina (729.30), W x LJ (734.44) and Corolix (747.37). The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the D^2 analysis.

4.1.8 Selection of Parents

The 15 genotypes which are showing maximum ranks in selection index values and the genetically divergent genotypes from various clusters were identified based on morphological and floral characters for hybridization. The important characters of the selected genotypes were presented in the Table 13.

4.2 Compatibility studies

Intervarietal crossings in all possible combinations involving the fifteen selected *Anthurium* genotypes was done, depending on the availability of receptive spadices and fresh pollen (Table. 14 and Plate.3). This was done with the aim of finding the compatibility between the varieties on the basis of

Percentage of spadix bearing berries

Percentage of berry set per spadix

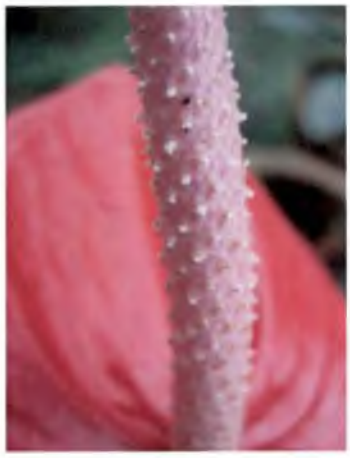
Percentage of seed germination.

In the present study varieties as well as hybrids selected as parents for crossing programme. A total of 127 crossings were attempted of which 80 were successful. The results of compatibility analysis carried out are present below.

Table 13. Morphological, floral character differentiation among the selected parents

Parents	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Selection Index Values (Rank)	Cluster Number
Acropolis White (AW)	27.00	0.00	5.44	123.43	49.17	420.00	White	1151.26 (12)	2
Carrie (C)	30.00	0.00	5.89	115.44	60.50	396.67	Red	1110.79 (14)	2
PR x DT (1)	39.22	1.33	5.78	10.46	57.50	498.67	Red	1563.69 (3)	3
Dragon Tongue (DT)	25.11	1.67	5.11	60.41	65.50	371.33	Red	1258.17 (7)	3
PR x OG	36.78	2.83	7.05	58.02	49.13	446.67	Orange	1215.06 (8)	2
KR x LR	31.17	0.00	6.11	59.37	50.50	518.67	Dark Red	1448.32 (5)	3
Liver Red (LR)	43.25	3.00	6.33	93.52	55.83	494.67	Deep Maroon	1691.88 (1)	7
OG x DT	37.66	1.17	6.42	99.54	45.00	514.67	Light orange	1347.45 (6)	2
PR x DT (2)	41.33	1.17	5.52	91.88	58.67	502.67	Dark Red	1523.05 (4)	3
PR x LR	39.00	2.00	5.93	57.85	43.60	414.00	Maroon	1590.19 (2)	6
Lay Jane (LJ)	28.67	0.67	6.27	46.99	50.78	440.00	Pink	1181.22 (11)	2
Ceasor Violet (CV)	29.17	0.00	6.00	92.28	48.67	408.00	Violet	1089.92 (15)	5
Fla Red (FR)	26.17	0.00	5.78	79.87	38.33	410.67	Red	1137.75 (13)	1
Flirt	32.50	0.00	6.83	67.12	44.17	330.67	Dark Red	1016.75 (22)	5
Esmeralda (E)	28.67	0.67	6.92	90.23	49.17	285.33	Green	952.70 (27)	1

X_1 - Plant height
X_2- Number of suckers per plant
X_3 -Number of leaves/spadices per plant
X_4 -Spathe size
X_5 -Inclination of candle with spathe
X_6 -Number of Flowers/spadix
X_7- Spathe Colour

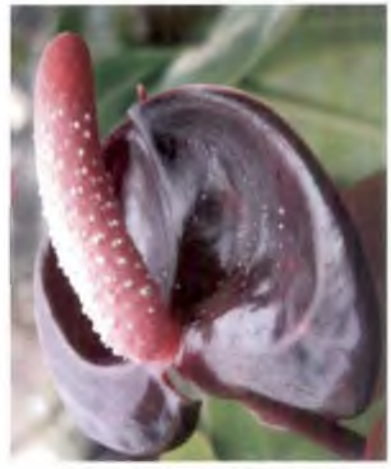


Male phase

Female phase

Male phase in Dragon's tounge

Male phase in PR x OG



Male phase in PR x LR

Male phase in Fla Red

Male phase in OG x DT

Female phase in Hawaiian Orange

Plate 3. Female and male phase in different genotypes of *Anthurium andreanum*

Table 14 Matrix showing the number of pollinations done in each combination among the genotypes of *A. andreanum*

	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E
AW	x	2	3	5	4	-	-	2	-	-	3	-	-	-	0
C	3	x	2	3	3	4	-	2	-	4	2	-	-	-	0
PR x DT (1)	3	3	x	4	3	-	3	2	-	5	-	-	2	-	0
DT	-	-	2	x	-	3	3	2	3	2	4	-	4	3	0
PR x OG	5	3	-	5	x	-	4	3	4	4	4	-	3	3	0
KR x LR	4	-	-	3	4	x	-	3	2	4	2	-	-	2	0
LR	-	-	4	4	3	-	x	4	-	-	3	-	4	-	0
OG x DT	5	2	-	2	4	3	4	x	4	3	-	-	2	2	0
PR x DT(2)	3	2	-	-	4	2	3	4	x	4	3	-	3	-	0
PR x LR	5	4	-	3	5	3	-	4	4	x	2	-	5	4	0
LJ	3	3	4	3	5	3	3	4	2	3	x	-	5	-	0
CV	-	-	-	4	4	-	3	3	-	2	3	x	-	3	0
FR	2	2	3	3	3	3	4	3	-	-	4	-	x	-	0
Flirt	3	-	2	2	4	-	-	3	-	-	4	-	-	x	0
E	2	2	3	3	4	-	2	2	-	-	2	-	2	4	x

x : Selfs not included in the present study
- : Cross combination not attempted.

Total possible crosses : 210 Number of crosses attempted :127

4.2.1 Compatibility based on performance of the female parents

4.2.1.1 Percentage of spadix bearing berries

The Percentage of spadix bearing berries for the successful crosses in female parent is given below (Table. 15).

Acropolis White (AW)

Six out of fourteen possible combinations involving this variety could be attempted (Plate.4). Out of six possible crosses attempted six were successful. Percentage of spadix bearing berries was highest for the crosses AW x (PR x OG) and AW x DT (100 per cent) and lowest for the crosses AW x C, AW x (PR x DT (1)), AW x (OG x DT) and AW x LJ (50 per cent).

Carrie (C)

Eight crosses could be attempted out of which six of them were successful (Plate.5). The crosses C x AW, C x DT and C x (KR x LR) showed 100 per cent successful while C x (PR x DT (1)), C x (PR x OG) and C x (PR x LR) recorded only 50 per cent success.

PR x DT (1)

A total of eight crosses could be attempted of which four of them were successful (Plate.5). The cross (PR x DT (1)) x (PR x OG) had higher success percentage (100 per cent) while the crosses (PR x DT (1)) x DT, (PR x DT (1)) x (PR x LR) and (PR x DT (1)) x FR recorded only 50 per cent.

Dragon Tongue (DT)

Out of nine crosses attempted only two were successful. All the crosses *i.e.*, DT x LR, and DT x FR showed 50 per cent success.

PR x OG

Ten out of fourteen possible combinations involving this variety could be attempted (Plate. 6). Out of ten possible crosses attempted ten were successful. Percentage of spadix bearing berries was highest for the crosses (PR x OG) x AW,

Table 15 Matrix showing percentage of candles bearing fruits in each combination

♀ / ♂	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E	Average
AW	x	50	50	100	100	-	-	50	-	-	50	-	-	-	-	66.67
C	100	x	50	100	50	100	-	0	-	50	0	-	-	-	-	56.25
PR x DT (1)	0	0	x	50	100	-	0	0	-	50	-	-	50	-	-	31.25
DT	-	-	0	x	-	0	50	0	0	0	0	-	50	0	-	11.11
PR x OG	100	50	-	100	x	-	100	100	100	100	100	-	100	50	-	90.00
KR x LR	100	-	-	50	50	x	-	100	0	50	50	-	-	0	-	50.00
LR	-	-	0	100	0	-	x	100	-	-	0	-	50	-	-	41.67
OG x DT	50	0	-	100	100	0	100	x	100	50	-	-	50	0	-	55.00
PR x DT(2)	0	0	-	-	100	50	0	100	x	100	50	-	100	-	-	55.56
PR x LR	100	100	-	50	100	0	-	0	100	x	0	-	100	100	-	65.00
LJ	50	0	50	0	100	0	100	100	50	100	x	-	100	-	-	59.09
CV	-	-	-	50	100	-	0	50	-	50	50	x	-	0	-	42.86
FR	0	0	50	100	50	0	50	50	-	-	0	-	x	-	-	33.33
Flirt	100	-	0	50	100	-	-	50	-	-	0	-	-	x	-	50.00
E	0	0	0	0	50	-	0	0	-	-	0	-	0	0	x	5.00

x : Selfs not included in the present study (Diagonals)

- : Cross combination not attempted.

0 : Cross attempted but not successful

AW x DT

AW x (PR x OG)

AW x [PR x DT (1)]

AW x (OG x DT)

C x AW

C x DT

Plate 4. Percentage of spadix bearing berries in different crosses attempted with Acropolis White and Carrie as a female parents

[PR x DT (1)] x FR

[PR x DT (1)] x (PR x LR)

[PR x DT (1)] x (PR x OG)

Plate 5. Percentage of spadix bearing berries in different crosses attempted with PR x DT (1) as a female parent

(PR x OG) x AW

(PR x OG) x AW

(PR x OG) x DT

(PR x OG) x DT

(PR x OG) x LR

(PR x OG) x LR

(PR x OG) x (PR x LR)

(PR x OG) x (PR x LR)

Plate 6. Percentage of spadix bearing berries in different crosses attempted PR x OG as female parent

(PR x OG) x (OG x DT)

(PR x OG) x (OG x DT)

(PR x OG) x FR

(PR x OG) x FR

(PR x OG) x C

(PR x OG) x LJ

(PR x OG) x [PR x DT (2)]

(PR x OG) x [PR x DT (2)]

Plate 6. (Continued) Percentage of spadix bearing berries in different crosses attempted PR x OG as female parent

(PR x OG) x DT, (PR x OG) x LR, (PR x OG) x (OG x DT), (PR x OG) x [PR x DT (2)] , (PR x OG) x (PR x LR), (PR x OG) x LJ, (PR x OG) x FR (100 per cent) and lowest for the crosses (PR x OG) x C and (PR x OG) x Flirt (50 per cent).

KR x LR

A total of eight crosses could be attempted of which six of them were successful (Plate.7). The cross (KR x LR) x AW and (KR x LR) x (OG x DT) had higher success percentage (100 per cent) while the crosses (KR x LR) x DT, (KR x LR) x (PR x OG), (KR x LR) x (PR x LR) and (KR x LR) x LJ recorded only 50 per cent.

Liver Red (LR)

A total of six crosses could be attempted of which three of them were successful. The crosss LR x DT and LR x (OG x DT) had higher success percentage (100 per cent) while the cross LR x FR recorded only 50 per cent.

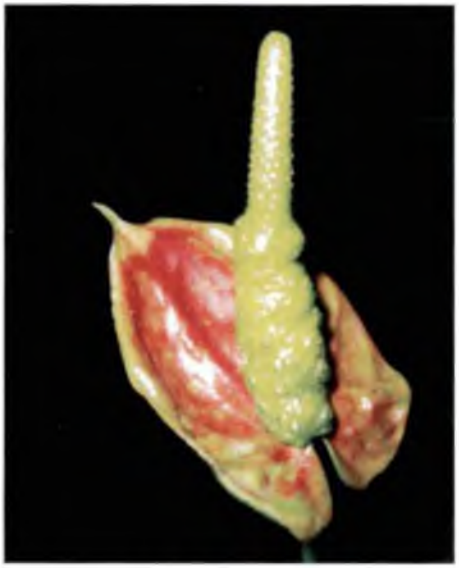
OG x DT

Out of ten crosses attempted seven were successful (Plate.8). Percentage of spadix bearing berries was highest for the crosses (OG x DT) x DT, (OG x DT) x (PR x OG), (OG x DT) x LR and (OG x DT) x [PR x DT (2)] (100 per cent) and 50 per cent for all the other successful crosses (OG x DT) x AW, (OG x DT) x (PR x LR) and (OG x DT) x FR.

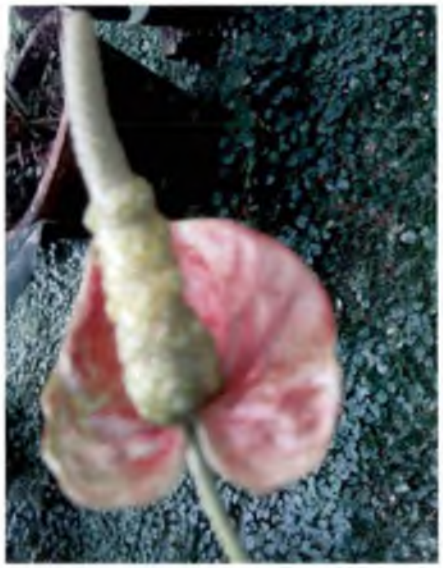
PR x DT (2)

A total of nine crosses could be attempted of which six of them were successful (Plate.9 and 10). The cross PR x DT (2) x (PR x OG), PR x DT (2) x (OG x DT), PR x DT (2) x (PR x LR) and PR x DT (2) x LJ had higher success percentage (100 per cent) while the crosses PR x DT (2) x (KR x LR) and PR x DT (2) x LJ recorded only 50 per cent.

FR x DT



FR x LR



FR x (OG x DT)

(KR x LR) x DT

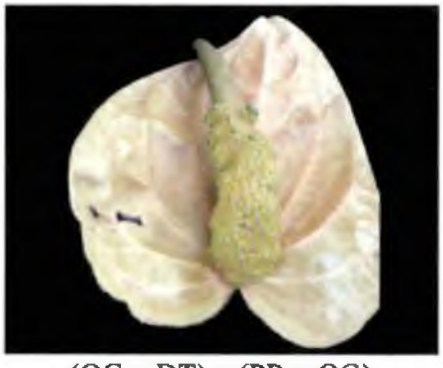
(KR x LR) x (PR x LR)

(KR x LR) x LJ

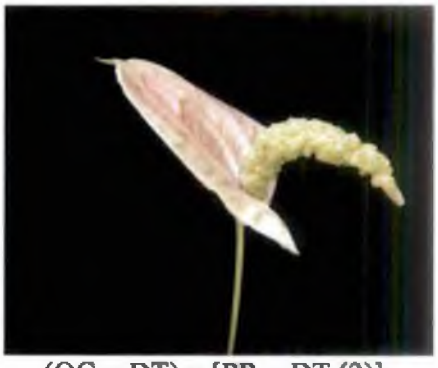
Plate 7. Percentage of spadix bearing berries in different crosses attempted
FR and KR x LR as female parents

(OG x DT) x AW

(OG x DT) x DT



(OG x DT) x (PR x OG)



(OG x DT) x [PR x DT (2)]

(OG x DT) x (PR x LR)

(OG x DT) x FR

(OG x DT) x LR

Plate 8. Percentage of spadix bearing berries in different crosses attempted with OG x DT as a female parent

[PR x DT (2)] x (OG x DT)

[PR x DT (2)] x (OG x DT)

[PR x DT (2)] x FR

[PR x DT (2)] x FR

[PR x DT (2)] x (PR x LR)

[PR x DT (2)] x (PR x LR)

Plate 9. Percentage of spadix bearing berries in different crosses attempted with PR x DT (2) as a female parent

[PR x DT (2)] x LJ

[PR x DT (2)] x (PR x OG)

(PR x LR) x AW

(PR x LR) x DT

(PR x LR) x (PR x OG)

(PR x LR) x FR

(PR x LR) x [PR x DT (2)]
at 2 month stage

(PR x LR) x [PR x DT (2)]
at 4 month stage

Plate 10. Percentage of spadix bearing berries in different crosses attempted with PR x DT (2) and PR x LR as a female parents

PR x LR

Ten crosses could be attempted out of which seven of them were successful. Percentage of spadix bearing berries was lowest for the crosse (PR x LR) x DT (50 per cent) and 100 per cent for all the other successful crosses *i.e.*, (PR x LR) x AW, (PR x LR) x C, (PR x LR) x (PR x OG), (PR x LR) x [PR x DT (2)], (PR x LR) x FR and (PR x LR) x Flirt.

Lay Jane (LJ)

Out of eleven crosses attempted eight were successful (Plate.11). Percentage of spadix bearing berries was highest for the crosses LJ x (PR x OG), LJ x LR, LJ x (OG x DT), LJ x (PR x LR) and LJ x FR (100 per cent) and 50 per cent for all the other successful crosses LJ x AW, LJ x (PR x DT (1)) and LJ x [PR x DT (2)].

Ceasor Violet (CV)

Seven crosses could be attempted out of which five of them were successful (Plate.12 and 13). The cross CV x (PR x OG) had higher success percentage (100 per cent). Percentage of spadix bearing berries was 50 per cent for all other successful crosses *i.e.*, CV x DT, CV x (OG x DT), CV x (PR x LR) and CV x LJ.

Fla Red (FR)

Out of nine crosses attempted five were successful (Plate.7). Percentage of spadix bearing berries was highest for the cross FR x DT (100 per cent) and 50 per cent for all the other successful crosses *i.e.*, FR x (PR x DT (1)), FR x (PR x OG), FR x LR and FR x (OG x DT).

Flirt

Six crosses could be attempted out of which four of them were successful (Plate.14). The percentage of spadix bearing berries was highest for the crosses Flirt x AW and Flirt x (PR x OG) (100 per cent) and lowest for the cross Flirt x (OG x DT) and Flirt x DT (50 per cent).

LJ x (PR x OG)

LJ x AW

LJ x (PR x LR)

LJ x LR at 1 month stage

LJ x LR at 3 months stage

LJ x [PR x DT (1)]

Plate 11. Percentage of spadix bearing berries in different crosses attempted Lady Jane as female parent

CV x (PR x OG)

CV x (PR x OG)

CV x (PR x OG)

CV x (PR x OG)

Plate 12 The cross CV x (PR x OG) at different stages of fruit maturity

CV x LJ

Esmaralda x (PR x OG)

Plate 13. Percentage of spadix bearing berries in different crosses attempted with CV and Esmaralda as a female parent

Flirt x AW

Flirt x DT

Flirt x AW

Flirt x (OG x DT)

Flirt x (PR x OG)

Plate 14. Percentage of spadix bearing berries in different crosses attempted Flirt as female parent

Esmeralda

Out of ten crosses attempted only one was successful (Plate.13). Percentage of spadix bearing berries 50 per cent for the cross Esmeralda x (PR x OG).

Among the 15 genotypes, the maximum percentage of candles bearing berries was obtained for PR x OG (90.00 per cent) followed by AW (66.67 per cent) and PR x LR (65.00 per cent). The lowest value 5 per cent was obtained for Esmeralda and 11.11 per cent for Dragon's Tongue.

4.2.1.2 Number of berries per spadix

The fruit of anthurium is a berry. The berries when ripe will be pushed out of the candle and they can be collected. The extrusion of berries takes place between 9 am and 10 am. The number of berries per candle obtained in various crosses are shown in Table 16. The fruit colour varies from yellow to dark red. In the present study duration from the day of pollination to the day of fruit maturity ranged from 4.5 to 7 months (Plate. 15).

Acropolis White (AW)

Among the six crosses which showed successful fruit set, the maximum number of berries per candle (80) was obtained for AW x (PR x OG) followed by AW x DT (45). Fruit set was lowest for the cross AW x C (12).

Carrie (C)

Out of seven successful crosses the cross C x DT showed highest number of berries per candle (30) followed by C x (PR x OG) with 25 berries and C x AW with 21 berries while fruit set was lowest for the cross C x (KR x LR) (12).

PR x DT (1)

Out of the four successful crosses, the highest number of berries per candle was seen for [PR x DT (1)] x DT (37) followed by [PR x DT (1)] x FR (26). The lowest number of berries per candle was seen for [PR x DT (1)] x (PR x LR) with 12 berries.

Table 16 Matrix showing average number of berries per spadix

♂ / ♀	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E	Average
AW	x	12	22	45	80	-	-	28	-	-	15	-	-	-	-	33.67
C	21	x	13	30	25	12	-	-	-	15	-	-	-	-	-	19.33
PR x DT (1)	-	-	x	37	24	-	-	-	-	12	-	-	26	-	-	24.75
DT	-	-	-	x	-	-	26	-	-	-	-	-	61	-	-	43.50
PR x OG	60	37	-	70	x	-	20	85	15	62	24	-	30	16	-	41.90
KR x LR	57	-	-	32	64	x	-	45	-	17	6	-	-	-	-	36.83
LR	-	-	-	83	-	-	x	60	-	-	-	-	72	-	-	71.67
OG x DT	15	-	-	46	8-	-	42	x	7-	21	-	-	30	-	-	43.43
PR x DT(2)	-	-	-	-	15	24	-	45	x	3-	12	-	18	-	-	24.00
PR x LR	51	48	-	15	28	-	-	-	46	x	-	-	23	17	-	32.57
LJ	30	-	38	-	61	-	18	18	28	33	x	-	28	-	-	31.75
CV	-	-	-	0	28	-	-	0	-	0	0	x	-	-	-	5.60
FR	-	-	42	54	29	-	43	31	-	-	-	-	x	-	-	39.80
Flirt	30	-	-	19	34	-	-	15	-	-	-	-	-	x	-	24.50
E	-	-	-	-	5	-	-	-	-	-	-	-	-	-	x	5.00

x : Selfs not included in the present study (Diagonals)

- : Not attempted and unsuccessful crosses

0 : Successful cross but not set berries in spadix

First month

Second month

Fourth month

Sixth month

Plate 15 ***Anthurium andreanum*** **at different stages of fruit maturity**

Dragon Tongue (DT)

Among the three successful crosses, the highest number of berries per candle was seen for DT x FR (61) and the lowest for DT x LR (26).

PR x OG

Among the ten crosses which showed fruit set, the cross (PR x OG) x (OG x DT) showed highest number of berries per candle (85) followed by (PR x OG) x DT (70). The lowest number of berries per candle was seen for (PR x OG) x PR x DT (2) with 15 berries.

KR x LR

Out of the six successful crosses, the cross (KR x LR) x (PR x OG) showed highest number of berries per candle (64) followed by (KR x LR) x AW (57). The lowest number of berries per candle was seen for (KR x LR) x LJ (6).

Liver Red (LR)

Out of the three successful crosses, the highest number of berries per candle was seen for LR x DT (83) followed by LR x FR (72) and LR x (OG x DT) with 60 berries (Plate.16).

OG x DT

Among the seven crosses which showed fruit set, the cross (OG x DT) x (PR x OG) showed highest number of berries per candle (80) followed by (OG x DT) x PR x DT (2) with 70 berries. The lowest number of berries per candle was seen for (OG x DT) x AW (15).

PR x DT (2)

The number of berries per candle in the crosses involving PR x DT (2) ranged from 12 in PR x DT (2) x LJ to 45 in PR x DT (2) x (OG x DT). The average number of berries per candle was 24.

LR x (OG x DT) at second month

LR x (OG x DT) at fourth month

LR x (OG x DT) at sixth month

Plate 16 The cross LR x (OG x DT) at different stages of fruit maturity

PR x LR

Seven crosses involving PR x LR were successful, of which (PR x LR) x AW (51) followed by (PR x LR) x C (48) showed the highest number of berries per candle. Fruit set was lowest for the cross (PR x LR) x DT (15).

Lay Jane (LJ)

Among the eight crosses which showed fruit set, the cross LJ x (PR x OG) showed highest number of berries per candle (61) followed by LJ x [PR x DT (1)] with 38 berries. The lowest number of berries per candle was seen for LJ x LR and LJ x (OG x DT) with 18 berries.

Ceasor Violet (CV)

In the crosses involving Ceasor Violet, only CV x (PR x OG) was successful which had an average of 28 berries per candle.

Fla Red (FR)

Among the five crosses which showed fruit set, the highest number of berries per candle was seen for FR x DT (54) followed by FR x LR (43). The lowest number of berries per candle was seen for FR x (PR x OG) with 29 berries.

Flirt

Out of the four successful crosses, the cross Flirt x (PR x OG) showed highest number of berries per candle (34) followed by Flirt x AW (30). The lowest number of berries per candle was seen for Flirt x (OG x DT) with 15 berries.

Esmeralda

Only the cross Esmeralda x (PR x OG) was successful which had average of five berries per candle.

Among the 15 genotypes, the highest average number of berries per candle was observed for Liver Red (71.67) with three crosses followed by PR x OG (41.90) with ten crosses and OG x DT (43.43) with seven crosses. This was

lowest for Esmeralda (5) with one cross. Among the individual cross combinations, (PR x OG) x (OG x DT) recorded highest number of fruits per candle (85) followed by LR x DT (83). The crosses (OG x DT) x (PR x OG) (80), LR x FR (72) and (PR x OG) x DT (70) also recorded higher number of fruits per candle. Esmeralda x (PR x OG) (5) and (KR x LR) x LJ (6) recorded lowest number of fruits per candle.

4.2.1.3 Percentage of berry set per candle

The Percentage of berry set per candle for the successful crosses in female parent is given below (Table. 17 and Plate. 17 and 18).

Acropolis White (AW)

Among the six crosses the highest percentage of fruit set (19.05 per cent) was obtained for AW x (PR x OG) followed by AW x (OG x DT) with 11.11 per cent and lowest for the cross AW x LJ (3.79 per cent).

Carrie (C)

In Carrie, the cross combination C x DT had the maximum percentage of fruit set (8.4 per cent) followed by C x (PR x OG) with 7 per cent and the lowest for the combination C x (KR x LR) with 3.02 per cent.

PR x DT (1)

The highest percentage of fruit set among the crosses of PR x DT (1) was for [PR x DT (1)] x FR (8.7 per cent) followed by [PR x DT (1)] x DT (7.42 per cent) and was the lowest in [PR x DT (1)] x (PR x LR) with 2.41 per cent.

Dragon's Tongue (DT)

In Dragon's Tongue, DT x FR had the highest percentage of fruit set (16.44 per cent) followed by DT x LR (7.76 per cent).

PR x OG

Among the crosses in PR x OG, the cross (PR x OG) x (OG x DT) recorded the highest percentage of fruit set (21.14 per cent) followed by (PR x

Table 17 Matrix showing average percentage of fruitset in each combination

	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E	Average
AW	x	5.06	5.82	10.71	19.05	-	-	11.11	-	-	3.79	-	-	-	-	9.26
C	5.88	x	5.46	8.40	7.00	3.02	-	-	-	3.80	-	-	-	-	-	5.59
PR x DT (1)	-	-	x	7.42	5.35	-	-	-	-	2.41	-	-	8.70	-	-	5.97
DT	-	-	-	x	-	-	7.76	-	-	-	-	-	16.44	-	-	12.10
PR x OG	13.42	9.2	-	15.66	x	-	4.47	21.14	3.36	13.87	5.46	-	7.36	3.98	-	9.79
KR x LR	10.98	-	-	6.85	12.33	x	-	9.64	-	3.28	2.73	-	-	-	-	7.64
LR	-	-	-	16.76	-	-	x	12.12	-	-	-	-	14.54	-	-	14.47
OG x DT	2.91	-	-	14.87	15.53	-	8.16	x	13.52	4.54	-	-	9.65	-	-	9.88
PR x DT(2)	-	-	-	-	2.99	7.97	-	8.96	x	5.98	2.98	-	3.98	-	-	5.48
PR x LR	12.32	11.59	-	4.02	6.76	-	-	-	11.11	x	-	-	5.55	4.11	-	7.92
LJ	7.58	-	8.64	-	13.86	-	4.55	4.09	10.61	8.33	x	-	6.36	-	-	8.00
CV	-	-	-	0	6.67	-	-	0	-	0	0	x	-	-	-	1.34
FR	-	-	11.35	14.63	7.86	-	10.49	8.40	-	-	-	-	x	-	-	10.55
Flirt	10.10	-	-	9.56	10.27	-	-	5.05	-	-	-	-	-	x	-	8.75
E	-	-	-	-	1.75	-	-	-	-	-	-	-	-	-	x	1.75

x : Selfs not included in the present study (Diagonals)

- : Not attempted and unsuccessful crosses

0 : Successful cross but not set berries in spadix

(PR x OG) x (PR x LR)

(PR x OG) x (OG x DT)

LR x (OG x DT)

(OG x DT) x [PR x DT (1)]

LJ x LR

AW x DT

Plate 17. Spadix with fruit set in different crosses

CV x (PR x OG)

[PR x DT (2)] x (OG x DT)

LJ x LR

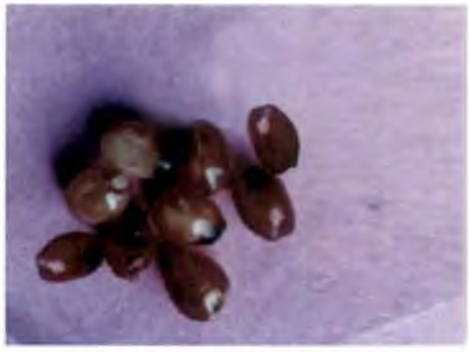
(PR x LR) x [PR x DT (2)]

C x DT

LR x FR

Plate 17. (Continued) Spadix with fruit set in different crosses

LR x (OG x DT)



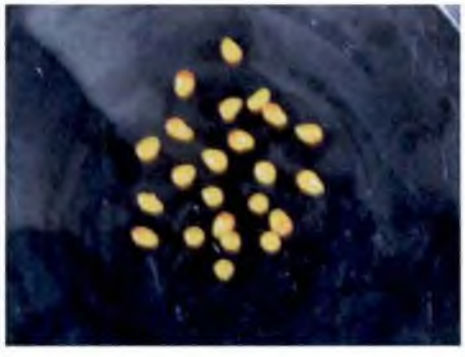
FR x LR

(PR x OG) x DT

[PR x DT (2)] x FR

AW x (PR x OG)

LR x DT



(KR x LR) x (OG x DT)

(OG x DT) x (PR x LR)

Plate 18. Ripe berries of different crosses in *Anthurium andreanum*

OG) x DT (15.66 per cent). The lowest fruit set (3.36 per cent) was observed in (PR x OG) x PR x DT (2).

KR x LR

In KR x LR, the cross combination (KR x LR) x (PR x OG) had the maximum percentage of fruit set (12.33 per cent) followed by (KR x LR) x AW (10.98 per cent) and the lowest for the combination (KR x LR) x LJ (2.73 per cent).

Liver Red (LR)

In Liver Red, the highest percentage of fruit set was obtained for LR x DT (16.76 per cent) followed by LR x FR (14.54 per cent) and LR x (OG x DT) (12.12 per cent).

OG x DT

Among the crosses in OG x DT, the cross (OG x DT) x (PR x OG) recorded the highest percentage of fruit set (15.53 per cent) followed by (OG x DT) x DT (14.87 per cent) and the lowest value in the combination (OG x DT) x AW (2.91 per cent).

PR x DT (2)

Among the crosses of PR x DT (2), the cross combination PR x DT (2) x (OG x DT) recorded the highest percentage of fruit set (8.96 per cent) followed by PR x DT (2) x (KR x LR) with 7.97 per cent and was the lowest in PR x DT (2) x LJ with 2.98 per cent.

PR x LR

In PR x LR, the highest percentage of fruit set was obtained for (PR x LR) x AW (12.32 per cent) followed by (PR x LR) x C (11.59 per cent). The lowest fruit set observed in (PR x LR) x DT (4.02 per cent).

Lay Jane (LJ)

Among the crosses of Lady Jane, the cross LJ x (PR x OG) recorded the highest percentage of fruit set (13.86 per cent) followed by LJ x PR x DT (2) with 10.61 per cent. The lowest fruit set (4.02 per cent) was observed in LJ x (OG x DT).

Ceasor Violet (CV)

The only successful cross in Ceasor Violet was CV x (PR x OG) which had a percentage of fruit set of 6.67 per cent.

Fla Red (FR)

Among the crosses of Fla Red, the highest percentage of fruit set was obtained for FR x DT (14.63 per cent) followed by FR x [PR x DT (1)] with 11.35 per cent. The lowest fruit set observed in FR x (PR x OG) (7.86 per cent).

Flirt

Among the crosses of Flirt, the cross Flirt x (PR x OG) recorded the highest percentage of fruit set (10.27 per cent) followed by Flirt x AW (10.10 per cent). The lowest fruit set (5.05 per cent) was observed in Flirt x (OG x DT).

Esmeralda

The only successful cross in Esmeralda was Esmeralda x (PR x OG) which had a percentage of fruit set of 1.75 per cent.

Among the successful crosses, the highest average percentage of fruit set was obtained for Liver Red (14.47 per cent) with three crosses followed by DT (12.10 per cent) with two crosses, FR (10.55 per cent) with five crosses, OG x DT (9.88 per cent) with seven crosses and PR x OG (9.79 per cent) with ten crosses. This was lowest for the CV (1.34 per cent) followed by Esmeralda (1.75 per cent) with one cross.

4.2.1.4 Number of seeds per berry

The fruit of anthurium *i.e.*, the berry contains one, two or rarely three seeds which is covered with a transparent sticky pulp. The data recorded on the number of seeds per berry for the 15 anthurium female parents are given below (Table 18).

Table 18 Number of seeds per berry and seed size among the crosses of *A. Andreanum* genotypes

Combination	Berries		Berries with single seed		Berries with two seeds	
	Single seed (per cent)	Two seeds (per cent)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
AW x C	58.33	46.67	3.50	2.53	2.97	1.82
AW x (PR x DT)	77.22	22.73	3.75	2.67	3.05	1.85
AW x DT	71.11	28.89	3.43	2.54	3.1	1.95
AW x (PR x OG)	77.50	22.50	4.17	3.45	3.53	2.27
AW x (OG x DT)	78.57	21.43	3.68	2.89	3.14	2.2
AW x LJ	93.33	6.67	2.91	2.17	2.52	1.75
C x AW	80.95	19.05	2.98	2.08	2.5	1.79
C x (PR x DT)	92.31	7.69	3.14	2.14	2.43	1.6
C x DT	83.33	16.67	3.28	2.51	2.78	1.75
C x (PR x OG)	76.00	24.00	3.43	2.46	2.95	1.97
C x (KR x LR)	83.33	16.67	2.88	2.10	2.43	1.65
C x (PR x LR)	86.67	13.33	3.18	2.37	2.6	1.95
(PR x DT) x DT	70.27	29.73	3.61	2.78	2.97	1.8
(PR x DT) x (PR x OG)	79.17	20.83	4.12	2.35	2.85	1.7
(PR x DT) x (PR x LR)	75.00	25.00	3.37	2.48	2.43	1.65
(PR x DT) x FR	63.33	36.67	3.42	2.63	2.5	1.95
DT x LR	76.92	23.08	2.75	2.35	2.35	1.75
DT x FR	68.85	31.15	3.68	2.27	2.95	1.85

Table 18 Continued

Combination	Berries		Berries with single seed		Berries with two seeds	
	Single seed (per cent)	Two seeds (per cent)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
(PR x OG) x AW	76.67	23.33	3.41	2.36	2.85	1.75
(PR x OG) x C	78.38	21.62	3.48	2.25	2.95	1.89
(PR x OG) x DT	82.86	17.14	3.67	2.78	3.1	1.95
(PR x OG) x LR	80.00	20	4.16	3.00	3.1	1.85
(PR x OG) x (OG x DT)	84.70	15.30	3.64	2.36	3.19	1.75
(PR x OG) x (PR x DT (2))	73.33	26.67	3.37	2.25	2.6	1.65
(PR x OG) x (PR x LR)	72.58	27.42	3.42	2.50	2.77	2.05
(PR x OG) x LJ	87.50	12.50	3.30	2.12	2.8	1.63
(PR x OG) x FR	60.00	40	3.60	2.10	2.85	1.75
(PR x OG) x Flirt	75.00	25	3.00	2.25	2.45	1.6
(KR x LR) x AW	66.67	33.33	4.17	3.00	3.28	2.5
(KR x LR) x DT	81.25	18.75	3.64	2.68	3.25	2.35
(KR x LR) x (PR x OG)	81.25	18.75	4.13	3.2	3.45	2.7
(KR x LR) x (OG x DT)	31.25	68.75	3.92	3.00	3.27	2.63
(KR x LR) x (PR x LR)	82.35	17.65	3.78	3.00	3.35	2.35
(KR x LR) x LJ	100	0	3.5	2.56	-	-
LR x DT	77.11	22.89	4.15	3.00	3.1	2
LR x (OG x DT)	70.00	30.00	3.37	2.56	2.75	1.95
LR x FR	83.33	16.67	3.40	2.60	2.85	2.2
(OG x DT) x AW	86.67	13.33	3.14	2.25	2.6	1.95

Table 18 Continued

Combination	Berries		Berries with single seed		Berries with two seeds	
	Single seed (per cent)	Two seeds (per cent)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
(OG x DT) x DT	84.78	15.22	3.67	2.75	3.2	2.05
(OG x DT) x (PR x OG)	83.75	16.25	3.17	2.33	2.45	1.7
(OG x DT) x LR	80.95	19.05	3.43	2.75	2.7	2.1
(OG x DT) x (PR x DT (2))	82.86	17.14	3.00	1.93	2.6	1.55
(OG x DT) x (PR x LR)	85.71	14.29	3.16	2.30	2.55	1.75
(OG x DT) x FR	83.33	16.67	3.20	2.50	2.5	1.95
[PR x DT (2)] x(PR x OG)	86.67	13.33	3.25	2.40	2.85	1.85
[PR x DT (2)] x(KR x LR)	70.83	29.17	2.96	2.17	2.45	1.65
[PR x DT (2)] x (OG x DT)	77.78	22.22	3.62	2.50	3.1	1.92
[PR x DT (2)] x (PR x LR)	80.00	20.00	3.68	2.65	2.95	1.85
[PR x DT (2)] x LJ	91.67	8.33	3.43	2.60	2.6	1.56
[PR x DT (2)] x FR	72.22	27.78	3.30	2.52	2.95	1.95
(PR x LR) x AW	68.63	31.37	3.87	2.38	3.6	1.75
(PR x LR) x C	75.00	25.00	3.82	2.68	2.7	1.7
(PR x LR) x DT	80.00	20.00	3.94	2.75	2.78	2.05
(PR x LR) x (PR x OG)	82.14	17.86	4.05	2.65	2.95	2
(PR x LR) x (PR x DT (2))	82.61	17.39	4.17	3.10	3.53	2.25
(PR x LR) x FR	73.91	26.09	3.70	2.65	3.19	2.25
(PR x LR) x Flirt	82.35	17.65	3.42	2.64	2.95	1.85

Table 18 Continued

Combination	Berries		Berries with single seed		Berries with two seeds	
	Single seed (per cent)	Two seeds (per cent)	Average length (mm)	Average width (mm)	Average length (mm)	Average width (mm)
LJ x AW	100	0	3.16	2.50	-	-
LJ x (PR x DT)	94.74	5.36	3.12	2.18	2.07	1.33
LJ x (PR x OG)	90.16	9.84	3.28	2.25	2.18	1.33
LJ x LR	100	0	3.10	2.28	-	-
LJ x (OG x DT)	88.89	11.11	2.98	2.10	1.94	1.27
LJ x (PR x DT (2))	100	0	3.10	2.25	-	-
LJ x (PR x LR)	100	0	2.88	2.40	-	-
LJ x FR	100	0	3.00	2.35	-	-
CV x (PR x OG)	78.57	21.43	2.93	2.25	2.5	1.77
FR x (PR x DT)	78.57	21.43	3.08	2.56	2.85	2.1
FR x DT	88.89	11.11	3.61	2.10	2.75	1.65
FR x (PR x OG)	79.31	20.69	3.75	2.65	3.1	2.17
FR x LR	37.21	62.79	4.18	2.75	3.52	2.25
FR x (OG x DT)	83.87	16.13	4.10	3.12	3.43	2.26
Flirt x AW	90.00	10.10	3.42	2.63	3.01	2.2
Flirt x DT	84.21	15.79	3.38	2.38	2.97	2
Flirt x (PR x OG)	76.47	23.53	3.40	2.68	3.22	2.1
Flirt x (OG x DT)	86.67	13.33	3.12	2.40	2.7	1.85
Esmaralda x (PR x OG)	100	0	2.25	1.33	0	0

Acropolis White (AW)

In Acropolis White, the percentage of berries with single seeds was highest for the cross AW x LJ (93.33 per cent) and the percentage of berries with double seeds was highest for the cross AW x C (46.67 per cent).

Carrie (C)

All the successful crosses involving Carrie produced berries with one as well as two seeds, of which the cross C x [PR x DT (1)] produced the highest percentage of berries with single seeds (92.31 per cent). The cross C x (PR x OG) had two seeds per berry in 24 per cent of the berries.

PR x DT (1)

Among the four successful crosses in PR x DT (1), the cross [PR x DT (1)] x (PR x OG) has 79.17 per cent of the berries with single seeds while the cross [PR x DT (1)] x FR had 36.67 per cent of berries with double seeds.

Dragon's Tongue (DT)

Among the two successful crosses in Dragon's Tongue, the cross DT x LR has 76.92 per cent of the berries with single seeds while the cross DT x FR had 31.15 per cent of berries with double seeds.

PR x OG

In PR x OG, the highest percentage of berries with single seeds was recorded for the cross (PR x OG) x LJ (87.50 per cent) followed by (PR x OG) x (OG x DT) with 84.70 per cent. The percentage of berries with double seeds was highest for the cross (PR x OG) x FR (40.00 per cent).

KR x LR

Among the three successful crosses involving KR x LR, (KR x LR) x LJ produced only single seeds. The cross (KR x LR) x (OG x DT) had berries with two seeds were more than those with single seeds (68.75 per cent).

Liver Red (LR)

Among the three successful crosses in Liver Red, the cross LR x FR had 83.33 per cent of the berries with single seeds while the cross LR x (OG x DT) had 30.00 per cent of berries with double seeds.

OG x DT

In OG x DT, the percentage of berries with single seeds was highest for the cross (OG x DT) x AW (86.67 per cent) and the percentage of berries with double seeds was highest for the cross (OG x DT) x LR (19.05 per cent).

PR x DT (2)

All the successful crosses involving PR x DT (2) produced berries with one as well as two seeds, of which the cross PR x DT (2) x LJ produced the highest percentage of berries with single seeds (91.67 per cent). The cross PR x DT (2) x (KR x LR) had two seeds per berry in 29.17 per cent of the berries.

PR x LR

Among the seven successful crosses involving in PR x LR, the cross (PR x LR) x [PR x DT (2)] produced the highest percentage of berries with single seeds (82.61 per cent) and the percentage of berries with double seeds was highest for the cross (PR x LR) x AW (31.37 per cent).

Lay Jane (LJ)

Among the eight successful crosses involving Lay Jane, LJ x AW, LJ x LR, LJ x [PR x DT (2)], LJ x (PR x LR) and LJ x FR, all produced berries with single seed only. The percentage of berries with double seeds was highest (11.11 per cent) for the cross LJ x (OG x DT).

Ceasor Violet (CV)

The only sucessful cross in Ceasor Violet *i.e.*, CV x (PR x OG) had 78.57 per cent of berries with single seed and 21.43 per cent of berries with double seeds.

Fla Red (FR)

In Fla Red, the percentage of berries with single seeds was highest for the cross FR x DT (88.89 per cent) and the percentage of berries with double seeds was highest for the cross FR x LR (62.79 per cent).

Flirt

Among the four successful crosses involving Flirt, the cross Flirt x AW produced the highest percentage of berries with single seeds (90.00 per cent) and the percentage of berries with double seeds was highest (23.53 per cent)for the cross Flirt x (PR x OG).

Esmeralda

Esmeralda x (PR x OG), which was only successful cross involving Esmeralda. The cross Esmeralda x (PR x OG) had 100 per cent of berries with single seed.

4.2.1.5 Seed Size

Size of seeds from the berries of same cross combination showed variation depending on whether the berries contained one or two seeds. As the number of seeds in the berry increased the average size of seeds decreased. The data recorded on the seed size are as follows (Table 18 and Plate.20).

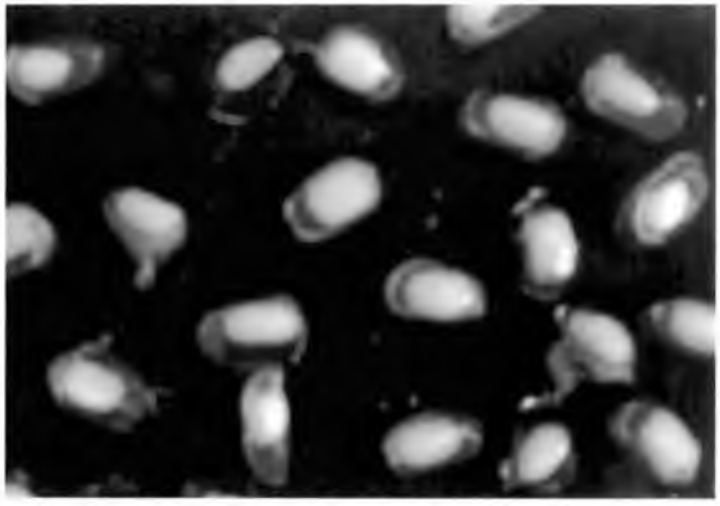
Acropolis White (AW)

In Acropolis White, the cross AW x (PR x OG) produced the largest seeds in single seeded as well as two seeded berries (4.17 x 3.45 mm and 3.53 x 2.27 mm). A smallest seed in the single seeded as well as two seeded berries was seen in AW x LJ (2.91x 2.17 mm and 2.52 x1.75 mm respectively).

Carrie (C)

The cross C x (PR x OG) had single seeded berries with the largest seed size, among the crosses of Carrie (3.43 x 2.46 mm). Largest seed size in double seeded berries also was seen in the same cross (2.95 x 1.97 mm). The cross C x

Seeds



Seeds - closeup view

Plate 20. Seeds of *Anthurium andreanum*

(KR x LR) had small seeds in the single seeded as well as two seeded berries (2.88 x 2.10 mm and 2.43x 1.65 mm respectively).

PR x DT (1)

Among the four successful crosses in PR x DT (1), the cross [PR x DT (1)] x (PR x OG) produced berries with the largest single seed size (4.12 x 2.35 mm). Among the two seeded berries [PR x DT (1)] x DT had the largest seed (2.97 x1.80 mm). The cross [PR x DT (1)] x (PR x LR) had the smallest seeds in single seeded as well as double seeded berries (3.37 x 2.48 mm and 2.43 x1.65 mm respectively).

Dragon's Tongue (DT)

In Dragon's Tongue, the largest seeds in single and double seeded berries was for the cross DT x FR (3.68 x 2.27 mm) and (2.95 x 1.85 mm) respectively.

PR x OG

In PR x OG, the cross (PR x OG) x LR had the largest seeds among single seeded berries (4.16 x 3.00 mm). Among the two seeded berries (PR x OG) x (OG x DT) had the largest seed (3.19 x 1.75 mm).

KR x LR

The cross (KR x LR) x AW produced berries with the largest single seed size (4.17 x 3.00 mm). Among the two seeded berries (KR x LR) x (PR x OG) had the largest seed (3.45 x 2.70 mm).

Liver Red (LR)

In Liver Red, the cross LR x DT produced the largest seeds in single seeded as well as two seeded berries (4.15 x 3.00 mm and 3.10 x 2.00 mm). A smallest seed in the single seeded as well as two seeded berries was seen in LR x (OG x DT) (3.37x 2.56 mm and 2.75 x1.95 mm respectively).

OG x DT

In OG x DT, the largest seeds in single and double seeded berries was for the cross (OG x DT) x DT (3.67 x 2.75 mm) and (3.20 x 2.05 mm) respectively. The smallest seed in the single seeded was seen in (OG x DT) x (PR x DT (2), which had an average size of 3.00 x 1.93 mm. Among the two seeded berries [(OG x DT) x (PR x OG)] had the smallest seed (2.45 x1.70 mm).

PR x DT (2)

The cross [PR x DT (2)] x (PR x LR) had the largest seed among single seeded berries (3.68 x 2.65 mm). Among the two seeded berries [PR x DT (2)] x (OG x DT) had the largest seed (3.10 x 1.92 mm).

PR x LR

The cross [(PR x LR) x (PR x DT (2)] produced the largest seeds in single seeded as well as two seeded berries (4.17 x 3.10 mm and 3.53 x 2.25 mm respectively). The smallest seed in the single seeded was seen in (PR x LR) x Flirt, which had an average size of 3.42 x 2.64 mm. Among the two seeded berries (PR x LR) x DT had the smallest seed (2.78 x 2.05 mm).

Lay Jane (LJ)

Among the eight successful crosses involving Lay Jane, LJ x AW, LJ x LR, LJ x [PR x DT (2)], LJ x (PR x LR) and LJ x FR, all produced berries with single seed only. The cross LJ x (PR x OG) had the largest seed in single as well as two seeded berries (3.28 x 2.25 mm and 2.18 x 1.33 mm).

Ceasor Violet (CV)

The only sucessful cross in Ceasor Violet was CV x (PR x OG) and the seed size of single seeded and double seeded berries for the cross CV x (PR x OG) was 2.93 x 2.25 mm and 2.50 x 1.77 mm.

Fla Red (FR)

In Fla Red, the cross FR x LR produced the largest seeds in single seeded as well as two seeded berries (4.18 x 2.75 mm and 3.52 x 2.25 mm respectively). The smallest seed in the single seeded was seen in FR x [PR x DT (1)], which had

an average size of 3.08 x 2.56 mm. Among the two seeded berries FR x DT had the smallest seed (2.75 x 1.65 mm).

Flirt

Among the four successful crosses involving in Flirt, the cross Flirt x AW had the largest seeds among single seeded berries (3.42 x 2.63 mm). Among the two seeded berries Flirt x (PR x OG) had the largest seed (3.22 x 2.10 mm).

Esmeralda

The only successful cross in Esmeralda, Esmeralda x (PR x OG) had only single seeded berries with seed size of 2.25 x1.33 mm.

Among the 15 genotypes, the cross FR x LR had the largest seeds among single seeded berries (4.17 x 2.75 mm). Among the two seeded berries AW x (PR x OG) had the largest seed (3.53 x 2.27 mm) followed by [(PR x LR) x (PR x DT (2)] (3.53 x 2.25 mm).

4.2.1.6 Seed germination (%)

From the harvested berries seeds were squeezed out and kept on moist cotton in petridishes after removing the sticky pulp around it. Seeds were obtained from 76 crosses (Table 19). Among these 73 crosses shown germination and the three crosses, DT x LR, (KR x LR) x LJ and Esmeralda x (PR x OG) did not germinate at all. In some ripe berries, seeds at the time of harvest had the tip of radicle emerging from the seed coat, such seeds germinated immediately. The number of days taken for germination ranged 4 to 9 days (Plate. 19).

Acropolis White (AW)

In Acropolis White, AW x (PR x OG) had the highest percentage of seed germination (53.60 per cent) while AW x LJ recorded the lowest (20.00 per cent).

Carrie (C)

In Carrie, the cross C x (PR x OG) had the highest germination 45.16 per cent followed by C x [PR x DT (1)] with 42.86 per cent. The cross C x (KR x LR) showed the lowest seed germination (21.43 per cent).

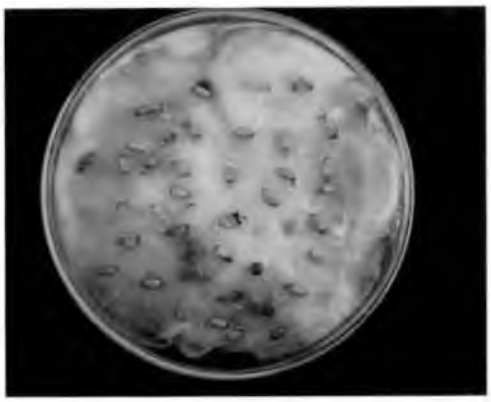
Table 19 Matrix showing average percentage of seed germination

♀ / ♂	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E	Average
AW	x	35.71	22.22	41.38	53.60	-	-	35.29	-	-	20.00	-	-	-	-	34.70
C	32	x	42.86	40.00	45.16	21.43	-	-	-	41.18	-	-	-	-	-	31.80
PR x DT (1)	-	-	x	33.33	37.93	-	-	-	-	20	-	-	24.32	-	-	28.90
DT	-	-	-	x	-	-	0	-	-	-	-	-	56.25	-	-	28.13
PR x OG	31.59	26.67	-	56.10	x	-	70.83	61.23	42.11	67.09	30.88	-	47.62	40.00	-	47.41
KR x LR	36.84	-	-	42.11	55.26	x	-	43.10	-	30	0	-	-	-	-	34.55
LR	-	-	-	33.33	-	-	x	44.87	-	-	-	-	53.57	-	-	43.92
OG x DT	23.53	-	-	40.68	51.63	-	57.32	x	48.78	29.17	-	-	41.18	-	-	41.76
PR x DT(2)	-	-	-	-	58.82	25.81	-	41.82	x	41.67	19.05	-	47.83	-	-	39.17
PR x LR	47.76	71.67	-	44.44	51.52	-	-	-	37.04	x	-	-	60.87	26.09	-	48.48
LJ	32.14	-	20.00	-	35.82	-	66.67	30.00	25.00	21.21	x	-	28.57	-	-	32.43
CV	-	-	-	-	38.23	-	-	-	-	-	-	x	-	-	-	38.23
FR	-	-	45.10	58.07	40.00	-	48.57	38.89	-	-	-	-	x	-	-	46.13
Flirt	30.3	-	-	27.27	44.12	-	-	29.14	-	-	-	-	-	x	-	32.71
E	-	-	-	-	0	-	-	-	-	-	-	-	-	-	x	0.00

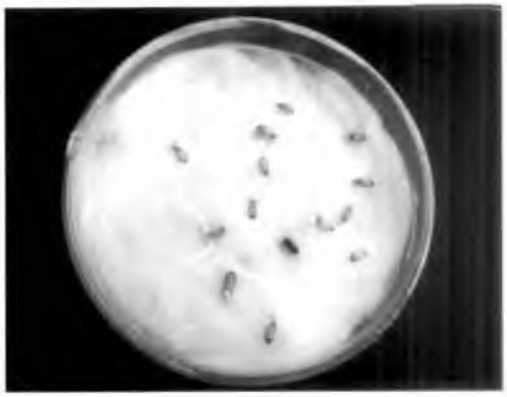
x: Self's not included in the present study (Diagonals)

- : Not attempted and unsuccessful crosses

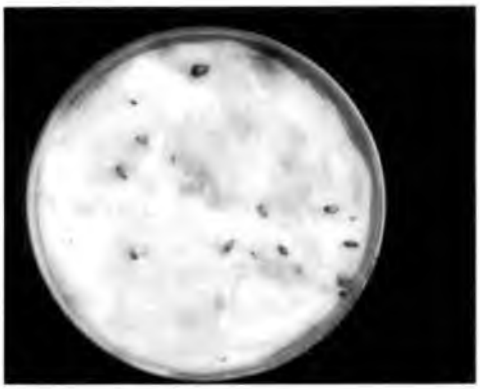
0 : Successful cross set berries in spadix but seeds not germinated



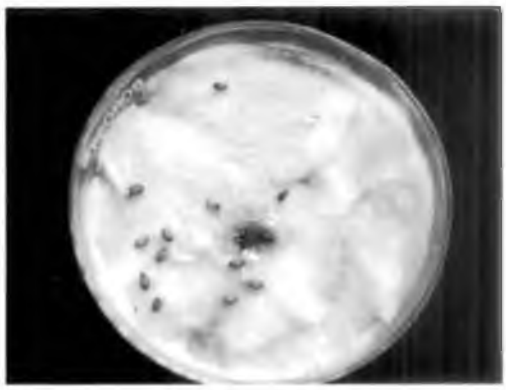
[PR x DT (1)] x (PR x OG)



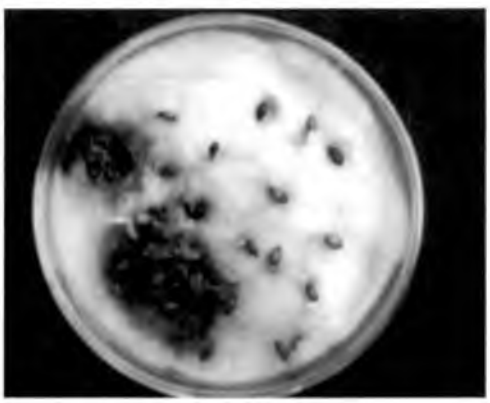
LJ x [PR x DT (1)]



(KR x LR) x LJ



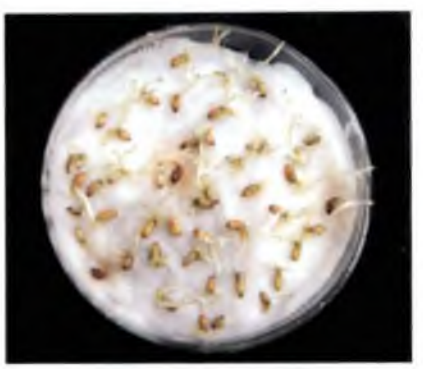
[PR x DT (2)] x LJ



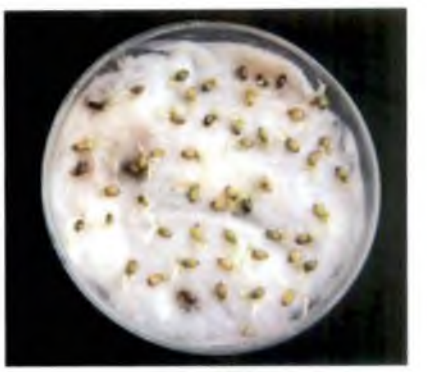
Flirt x DT

DT x LR

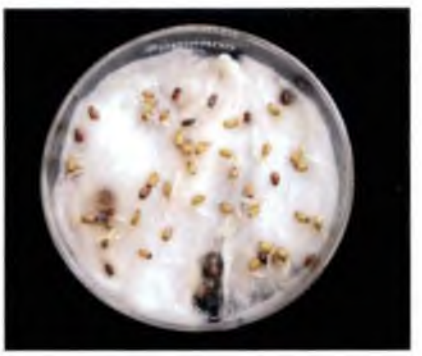
Plate 19. (Continued) Seed germination of different crosses in *Anthurium andreanum*



AW x (PR x OG)

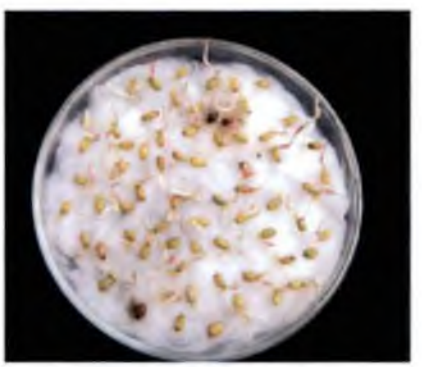


LJ x FR

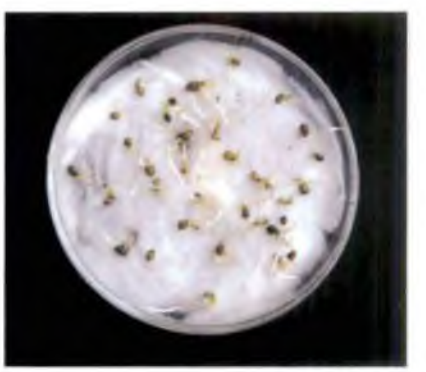


(OG x DT) x DT

FR x LR

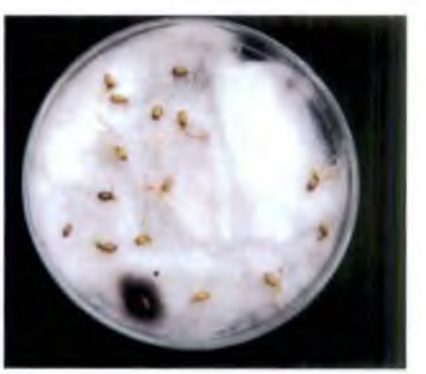


(PR x OG) x LR



LJ x LR

[PR x DT (2)] x (KR x LR)



C x (KR x LR)

Plate 19. Seed germination of different crosses in *Anthurium andreanum*

PR x DT (1)

[PR x DT (1)] x (PR x OG) had the highest percentage of seed germination (37.93 per cent) among the crosses of PR x DT (1) followed by [PR x DT (1)] x DT (33.33 per cent) and was the lowest in [PR x DT (1)] x (PR x LR) with 20.00 per cent.

Dragon's Tongue (DT)

In Dragon's Tongue, DT x FR had the highest percentage of seed germination (56.25 per cent) and the seeds of DT x LR did not germinate.

PR x OG

Among the crosses in PR x OG, the cross (PR x OG) x LR recorded the highest percentage of seed germination (70.83 per cent) followed by (PR x OG) x (PR x LR) with 67.09 per cent and the lowest seed germination observed in (PR x OG) x C (26.67 per cent).

KR x LR

In KR x LR, the cross combination (KR x LR) x (PR x OG) had the maximum percentage of seed germination (55.26 per cent) and the lowest for the combination (KR x LR) x (PR x LR) with 30.00 per cent. The seeds of (KR x LR) x LJ did not germinate.

Liver Red (LR)

In Liver Red, the highest percentage of seed germination was obtained for LR x FR (53.57 per cent) while LR x DT (33.33 per cent) had the lowest value.

OG x DT

Among the crosses in OG x DT, the cross (OG x DT) x LR recorded the highest percentage of seed germination (57.32 per cent) followed by (OG x DT) x (PR x OG) (51.63 per cent) and the lowest value in the combination (OG x DT) x AW (23.53 per cent).

PR x DT (2)

Among the crosses of PR x DT (2), the cross combination PR x DT (2) x (PR x OG) recorded the highest percentage of seed germination (58.82 per cent)

followed by PR x DT (2) x FR (47.83 per cent) and was the lowest in PR x DT (2) x LJ (19.05 per cent).

PR x LR

In PR x LR, the highest percentage of seed germination was obtained for (PR x LR) x C (71.67 per cent) followed by (PR x LR) x FR (60.87 per cent). The lowest seed germination observed in (PR x LR) x Flirt (26.09 per cent).

Lay Jane (LJ)

Among the crosses of Lady Jane, the cross LJ x LR recorded the highest percentage of seed germination (66.67 per cent) followed by LJ x (PR x OG) with 35.82 per cent. The lowest seed germination (20.00 per cent) was observed in LJ x [PR x DT (1)].

Ceasor Violet (CV)

The only successful cross in Ceasor Violet was CV x (PR x OG) which had a 38.23 per cent of seed germination.

Fla Red (FR)

Among the crosses of Fla Red, the highest percentage of seed germination was obtained for FR x DT (58.07 per cent) followed by FR x LR (48.57 per cent). The lowest seed germination observed in FR x (OG x DT) (38.89 per cent).

Flirt

Among the crosses of Flirt, the cross Flirt x (PR x OG) recorded the highest percentage of seed germination (44.12 per cent) followed by Flirt x AW (30.30 per cent). The lowest seed germination was observed in Flirt x DT (27.27 per cent).

Esmeralda

The only successful cross in Esmeralda was Esmeralda x (PR x OG), the seeds of this cross did not germinate.

Among the 15 genotypes, PR x LR had the highest percentage of seed germination (48.48 per cent) followed by PR x OG (47.41 per cent) and Fla Red

(46.13 per cent). The lowest percentage was recorded for Esmeralda, as the seeds from its only successful cross did not germinate at all.

4.2.1.7 Seedling Viability

Survival percentage of seedlings at four to six month stage was recorded and presented in Table 20 (Plate. 21, 22 and 23). Out of 73 combinations that germinated successfully, the seedlings belonging to the 16 crosses did not survive beyond six months. The cross (KR x LR) x DT showed 81.25 per cent seedling survival followed by (KR x LR) x (PR x OG), [PR x DT (2)] x (PR x OG) and [PR x DT (2)] x (PR x LR) with 80 per cent. Seedlings of the crosses (OG x DT) x LR, (OG x DT) x FR, [PR x DT (2)] x (OG x DT), [PR x DT (1)] x FR, LR x DT, [PR x DT (1)] x DT and (PR x LR) x DT also showed good survival percentage (75 to 78.72 per cent).

Among the genotypes, the highest average seedling survival was recorded for Liver Red (69.93 per cent) followed by PR x DT (1) (68.50 per cent) and low seedling survival recorded for Lady Jane (15.41 per cent).

4.2.2 Compatibility parameters based on the performance of the fifteen genotypes as pollen parents

Highest percentage of candles bearing fruits was shown by PR x OG (76.92 per cent) followed by Fla Red (66.67 per cent), Dragon's Tongue (65.38 per cent) and PR x LR (61.11 per cent). Lowest percentage were recorded for Flirt and KR x LR (21.43 per cent) (Table. 21).

Number of fruits per candle was the highest for the genotype [PR x DT (2)] (39.75) followed by PR x OG (39.42), Dragon's Tongue (39.18) and Acropolis white (37.71). In LJ, Flirt and KR x LR the number of fruits were relatively lower (14.25, 16.5 and 18 respectively).

Higher percentage fruit set was observed for the genotypes Dragon's Tongue (9.90 per cent), [PR x DT (2)] (9.65 per cent), PR x OG (9.12 per cent) and Fla Red (9.07 per cent). It was lowest in Lady Jane (2.77 per cent) and Flirt (4.04 per cent).

Table 20 Matrix showing survival percentage of seedlings at four to six months stage

♀ \ ♂	AW	C	PR x DT (1)	DT	PR x OG	KR x LR	LR	OG x DT	PR x DT(2)	PR x LR	LJ	CV	FR	Flirt	E	Average
AW	x	66.67	50.00	70.83	73.08	-	-	58.33	-	-	0	-	-	-	-	53.15
C	0	x	66.67	57.14	64.29	0	-	-	-	0	-	-	-	-	-	31.35
PR x DT (1)	-	-	x	75.00	54.55	-	-	-	-	66.67	-	-	77.78	-	-	68.50
DT	-	-	-	x	-	-	-	-	-	-	-	-	64.44	-	-	64.44
PR x OG	58.33	0	-	73.91	x	-	64.71	71.67	62.50	67.93	0	-	70.00	0	-	46.91
KR x LR	39.29	-	-	81.25	80.00	x	-	64.00	-	66.67	-	-	-	-	-	66.24
LR	-	-	-	76.47	-	-	x	71.11	-	-	-	-	62.22	-	-	69.93
OG x DT	0	-	-	70.83	72.92	-	78.72	x	60.00	71.43	-	-	78.57	-	-	54.06
PR x DT(2)	-	-	-	-	80.00	0	-	78.26	x	80.00	0	-	72.72	-	-	51.83
PR x LR	44.44	41.86	-	75.00	70.59	-	-	-	55.00	x	-	-	71.43	-	-	59.72
LJ	0	-	0	-	37.50	-	58.33	0	0	42.85	x	-	0	0	-	15.41
CV	-	-	-	-	38.46	-	-	-	-	-	-	x	-	-	-	38.46
FR	-	-	65.22	55.56	71.43	-	55.88	64.29	-	-	-	-	x	-	-	62.48
Flirt	40.00	-	-	33.33	53.33	-	-	60.00	-	-	-	-	-	x	-	46.67
E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	0.00

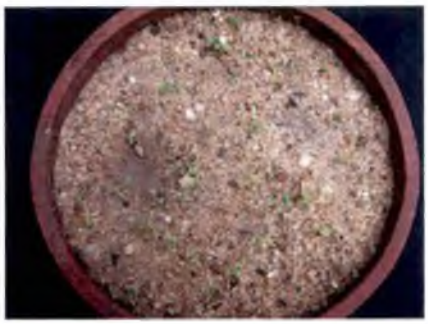
x : Self's not included in the present study (Diagonals)

- : Not attempted and unsuccessful crosses

0 : Seeds germinated but seedlings not survived more than 6 months

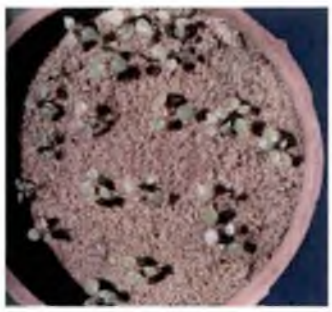
AW x DT

LJ x LR



(PR x OG) x FR

(OG x DT) x LR



[PR x DT (2)] x (PR x LR)

(PR x OG) x (OG x DT)

LR x FR

Plate 21. Seedlings of different crosses in *Anthurium andreanum*

Stage 1

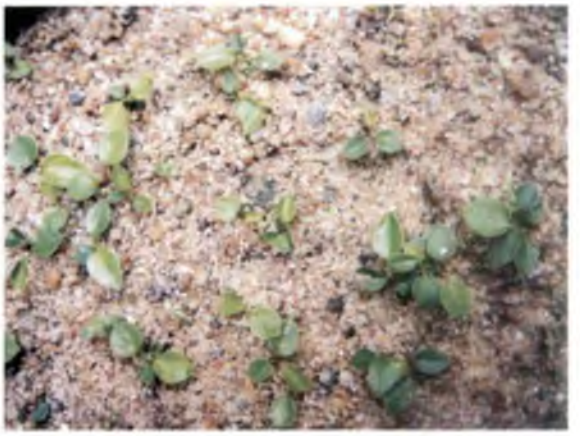
Stage 2

Stage 3

Stage 4

Plate 22. Various stages of seedling death at four month stage

Seedlings at 2 month stage



Seedlings at 2 month stage

Seedlings at 4 month stage

Seedlings at 4 month stage

Seedlings at 6 month stage

Seedlings at 6 month stage

Plate 23. Various stages in seedling development

Percentage of seed germination was the highest for Fla Red (45.03 per cent) and lowest for Lady Jane (13.11 per cent).

A novel method for easy computation and understanding of compatibility reactions was devised by Renu (2000). Compatibility reactions of the crosses are converted into a linear scale. Scoring of the compatibility reactions based on the percentage of fruiting candles, fruit set and seed germination on a scale ranging from zero to nine.. A similar type of classification is done in the present study also. Accordingly, the percentage of fruiting candles which ranged from 0 to 100 per cent were divided into four compatibility classes as

High	(100-76 per cent)	- A
Medium	(75-26 per cent)	- B
Low	(25-1 per cent)	- C
Nil	(0 per cent)	- D

The percentage of fruit set in the present study ranged from 1.75 per cent to 21.14 per cent and these values were classified into four classes as

High	(above 30 per cent)	- A
Medium	(20-29 per cent)	- B
Low	(1-19 per cent)	- C
Nil	(0 per cent)	- D

The percentage of seed germination, which ranged from 19.05 to 71.67 per cent, was classified as

High	(above 80 per cent)	- A
Medium	(50-79 per cent)	- B
Low	(1-49 per cent)	- C
Nil	(0 per cent)	- D

The crosses of the fifteen female parents were linearly scored on the basis of percentage of fruiting candles, fruit set and seed germination as shown in the Table 22. From the Table it was found that the female parents PR x OG, PR x

Table 21 Compatibility parameters based on the performance of the fifteen genotypes of *A. andreanum* as pollen parents

Genotypes	Percentage of candle bearing fruit	Number of fruits per candle	Percentage fruit set	Percentage seed germination
AW	54.55	37.71	9.03	33.45
C	22.22	32.33	8.62	44.68
PR x DT (1)	25.00	28.75	7.82	32.55
DT	65.38	39.18	9.90	37.88
PR x OG	76.92	39.42	9.12	39.11
KR x LR	21.43	18.00	5.49	23.62
LR	44.44	29.80	7.09	38.94
OG x DT	50.00	36.33	7.11	40.54
PR x DT(2)	58.33	39.75	9.65	38.23
PRxLR	61.11	23.75	5.28	35.76
LJ	60.00	14.25	2.77	13.11
CV*	0.00	0.00	0.00	0.00
FR	66.67	36.00	9.07	45.03
Flirt	21.43	16.50	4.04	40.00
E*	0.00	0.00	0.00	0.00

* No pollen emergence occurred during the crossing period

Table 22 Compatibility score on the basis of the performance of 15 genotypes of *A. andreanum* as female parents

Crosses	Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
AW x C	B	C	C	4	
AW x [PR x DT(1)]	B	C	C	4	
AW x DT	A	C	C	5	
AW x [PR x OG]	A	C	B	6	
AW x [KR x LR]	D	D	D	0	
AW x LR	D	D	D	0	
AW x [OG x DT]	B	C	C	4	
AW x [PR x DT(2)]	D	D	D	0	27
AW x [PR x LR]	D	D	D	0	
AW x LJ	B	C	C	4	
AW x CV	D	D	D	0	
AW x FR	D	D	D	0	
AW x Flirt	D	D	D	0	
AW x E	D	D	D	0	
C x AW	A	C	C	5	
C x [PR x DT(1)]	B	C	C	4	
C x DT	A	C	C	5	
C x [PR x OG]	B	C	C	4	
C x [KR x LR]	A	C	C	5	
C x LR	D	D	D	0	
C x [OG x DT]	D	D	D	0	
C x [PR x DT(2)]	D	D	D	0	
C x [PR x LR]	B	C	C	4	
C x LJ	D	D	D	0	27
C x CV	D	D	D	0	
C x FR	D	D	D	0	
C x Flirt	D	D	D	0	
C x E	D	D	D	0	
[PR x DT(1)] x AW	D	D	D	0	
[PR x DT(1)] x C	D	D	D	0	
[PR x DT(1)] x DT	B	C	C	4	
[PR x DT(1)] x [PR x OG]	A	C	C	5	
[PR x DT(1)] x [KR x LR]	D	D	D	0	
[PR x DT(1)] x LR	D	D	D	0	
[PR x DT(1)] x [OG x DT]	D	D	D	0	
[PR x DT(1)] x [PR x DT(2)]	D	D	D	0	
[PR x DT(1)] x [PR x LR]	B	C	C	4	17
[PR x DT(1)] x LJ	D	D	D	0	
[PR x DT(1)] x CV	D	D	D	0	
[PR x DT(1)] x FR	B	C	C	4	
[PR x DT(1)] x Flirt	D	D	D	0	
[PR x DT(1)] x E	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 22 Continued

Crosses	Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
DT x AW	D	D	D	0	
DT x C	D	D	D	0	
DT x [PR x DT(1)]	D	D	D	0	
DT x [PR x OG]	D	D	D	0	
DT x [KR x LR]	D	D	D	0	
DT x LR	B	C	D	3	
DT x [OG x DT]	D	D	D	0	
DT x [PR x DT(2)]	D	D	D	0	
DT x [PR x LR]	D	D	D	0	
DT x LJ	D	D	D	0	8
DT x CV	D	D	D	0	
DT x FR	B	C	B	5	
DT x Flirt	D	D	D	0	
DT x E	D	D	D	0	
[PR x OG] x AW	A	C	C	5	
[PR x OG] x C	B	C	C	4	
[PR x OG] x [PR x DT(1)]	D	D	D	0	
[PR x OG] x DT	A	C	B	6	
[PR x OG] x [KR x LR]	D	D	D	0	
[PR x OG] x LR	A	C	B	6	
[PR x OG] x [OG x DT]	A	B	B	7	
[PR x OG] x [PR x DT(2)]	A	C	C	5	53
[PR x OG] x [PR x LR]	A	C	B	6	
[PR x OG] x LJ	A	C	C	5	
[PR x OG] x CV	D	D	D	0	
[PR x OG] x FR	A	C	C	5	
[PR x OG] x Flirt	B	C	C	4	
[PR x OG] x E	D	D	D	0	
[KR x LR] x AW	A	C	C	5	
[KR x LR] x C	D	D	D	0	
[KR x LR] x [PR x DT(1)]	D	D	D	0	
[KR x LR] x DT	B	C	C	4	
[KR x LR] x [PR x OG]	B	C	B	5	
[KR x LR] x LR	D	D	D	0	
[KR x LR] x [OG x DT]	A	C	C	5	
[KR x LR] x [PR x DT(2)]	D	D	D	0	26
[KR x LR] x [PR x LR]	B	C	C	4	
[KR x LR] x LJ	B	C	D	3	
[KR x LR] x CV	D	D	D	0	
[KR x LR] x FR	D	D	D	0	
[KR x LR] x Flirt	D	D	D	0	
[KR x LR] x E	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 22 Continued

Crosses	Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
LR x AW	D	D	D	0	
LR x C	D	D	D	0	
LR x [PR x DT(1)]	D	D	D	0	
LR x DT	A	C	C	5	
LR x [PR x OG]	D	D	D	0	
LR x [KR x LR]	D	D	D	0	
LR x [OG x DT]	A	C	C	5	
LR x [PR x DT(2)]	D	D	D	0	15
LR x [PR x LR]	D	D	D	0	
LR x LJ	D	D	D	0	
LR x CV	D	D	D	0	
LR x FR	B	C	B	5	
LR x Flirt	D	D	D	0	
LR x E	D	D	D	0	
[OG x DT] x AW	B	C	C	4	
[OG x DT] x C	D	D	D	0	
[OG x DT] x [PR x DT(1)]	D	D	D	0	
[OG x DT] x DT	A	C	C	5	
[OG x DT] x [PR x OG]	A	C	B	6	
[OG x DT] x [KR x LR]	D	D	D	0	
[OG x DT] x LR	A	C	B	6	
[OG x DT] x [PR x DT(2)]	A	C	C	5	
[OG x DT] x [PR x LR]	B	C	C	4	34
[OG x DT] x LJ	D	D	D	0	
[OG x DT] x CV	D	D	D	0	
[OG x DT] x FR	B	C	C	4	
[OG x DT] x Flirt	D	D	D	0	
[OG x DT] x E	D	D	D	0	
AW	D	D	D	0	
[PR x DT(2)] x C	D	D	D	0	
[PR x DT(2)] x [PR x	D	D	D	0	
[PR x DT(2)] x DT(1)]	D	D	D	0	
[PR x DT(2)] x DT	A	C	B	6	
[PR x DT(2)] x [PR x OG]	B	C	C	4	
[PR x DT(2)] x [KR x LR]	D	D	D	0	
[PR x DT(2)] x LR	A	C	C	5	29
[PR x DT(2)] x [OG x DT]	A	C	C	5	
[PR x DT(2)] x [PR x LR]	B	C	C	4	
[PR x DT(2)] x LJ	D	D	D	0	
[PR x DT(2)] x CV	A	C	C	5	
[PR x DT(2)] x FR	D	D	D	0	
[PR x DT(2)] x Flirt	D	D	D	0	
[PR x DT(2)] x E					

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 22 Continued

Crosses	Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
[PR x LR] x AW	A	C	C	5	
[PR x LR] x C	A	C	B	6	
[PR x LR] x [PR x DT(1)]	D	D	D	0	
[PR x LR] x DT	B	C	B	5	
[PR x LR] x [PR x OG]	A	C	B	6	
[PR x LR] x [KR x LR]	D	D	D	0	
[PR x LR] x LR	D	D	D	0	
[PR x LR] x [OG x DT]	D	D	D	0	38
[PR x LR] x [PR x DT(2)]	A	C	C	5	
[PR x LR] x LJ	D	D	D	0	
[PR x LR] x CV	D	D	D	0	
[PR x LR] x FR	A	C	B	6	
[PR x LR] x Flirt	A	C	C	5	
[PR x LR] x E	D	D	D	0	
LJ x AW	B	C	C	4	
LJ x C	D	D	D	0	
LJ x [PR x DT(1)]	B	C	C	4	
LJ x DT	D	D	D	0	
LJ x [PR x OG]	A	C	C	5	
LJ x [KR x LR]	D	D	D	0	
LJ x LR	A	C	B	6	
LJ x [OG x DT]	A	C	C	5	
LJ x [PR x DT(2)]	B	C	C	4	38
LJ x [PR x LR]	A	C	C	5	
LJ x CV	D	D	D	0	
LJ x FR	A	C	C	5	
LJ x Flirt	D	D	D	0	
LJ x E	D	D	D	0	
CV x AW	D	D	D	0	
CV x C	D	D	D	0	
CV x [PR x DT(1)]	D	D	D	0	
CV x DT	B	D	C	2	
CV x [PR x OG]	A	C	D	3	
CV x [KR x LR]	D	D	D	0	
CV x LR	D	D	D	0	
CV x [OG x DT]	B	D	D	2	13
CV x [PR x DT(2)]	D	D	D	0	
CV x [PR x LR]	B	D	D	2	
CV x LJ	B	D	D	2	
CV x FR	D	D	D	0	
CV x Flirt	D	D	D	0	
CV x E	D	D	D	0	

Å = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 22 Continued

Crosses	Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
FR x AW	D	D	D	0	
FR x C	D	D	D	0	
FR x [PR x DT(1)]	B	C	C	4	
FR x DT	A	C	B	6	
FR x [PR x OG]	B	C	C	4	
FR x [KR x LR]	D	D	D	0	
FR x LR	B	C	C	4	22
FR x [OG x DT]	B	C	C	4	
FR x [PR x DT(2)]	D	D	D	0	
FR x [PR x LR]	D	D	D	0	
FR x LJ	D	D	D	0	
FR x CV	D	D	D	0	
FR x Flirt	D	D	D	0	
FR x E	D	D	D	0	
Flirt x AW	A	C	C	5	
Flirt x C	D	D	D	0	
Flirt x [PR x DT(1)]	D	D	D	0	
Flirt x DT	B	C	C	4	
Flirt x [PR x OG]	A	C	C	5	
Flirt x [KR x LR]	D	D	D	0	
Flirt x LR	D	D	D	0	
Flirt x [OG x DT]	B	C	C	4	18
Flirt x [PR x DT(2)]	D	D	D	0	
Flirt x [PR x LR]	D	D	D	0	
Flirt x LJ	D	D	D	0	
Flirt x CV	D	D	D	0	
Flirt x FR	D	D	D	0	
Flirt x E	D	D	D	0	
E x AW	D	D	D	0	
E x C	D	D	D	0	
E x [PR x DT(1)]	D	D	D	0	
E x DT	D	D	D	0	
E x [PR x OG]	B	C	D	3	
E x [KR x LR]	D	D	D	0	
E x LR	D	D	D	0	
E x [OG x DT]	D	D	D	0	3
E x [PR x DT(2)]	D	D	D	0	
E x [PR x LR]	D	D	D	0	
E x LJ	D	D	D	0	
E x CV	D	D	D	0	
E x FR	D	D	D	0	
E x Flirt	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 23 Compatibility score on the basis of the performance of 15 genotypes of *A. andreanum* as male parents

Crosses		Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
C	x AW	A	C	C	5	
[PR x DT(1)]	x AW	D	D	D	0	
DT	x AW	D	D	D	0	
[PR x OG]	x AW	A	C	C	5	
[KR x LR]	x AW	A	C	C	5	
LR	x AW	D	D	D	0	
[OG x DT]	x AW	B	C	C	4	
[PR x DT(2)]	x AW	D	D	D	0	33
[PR x LR]	x AW	A	C	C	5	
LJ	x AW	B	C	C	4	
CV	x AW	D	D	D	0	
FR	x AW	D	D	D	0	
Flirt	x AW	A	C	C	5	
E	x AW	D	D	D	0	
AW	x C	B	C	C	4	
[PR x DT(1)]	x C	D	D	D	0	
DT	x C	D	D	D	0	
[PR x OG]	x C	B	C	C	4	
[KR x LR]	x C	D	D	D	0	
LR	x C	D	D	D	0	
[OG x DT]	x C	D	D	D	0	14
[PR x DT(2)]	x C	D	D	D	0	
[PR x LR]	x C	A	C	B	6	
LJ	x C	D	D	D	0	
CV	x C	D	D	D	0	
FR	x C	D	D	D	0	
Flirt	x C	D	D	D	0	
E	x C	D	D	D	0	
AW	x [PR x DT(1)]	B	C	C	4	
C	x [PR x DT(1)]	B	C	C	4	
DT	x [PR x DT(1)]	D	D	D	0	
[PR x OG]	x [PR x DT(1)]	D	D	D	0	
[KR x LR]	x [PR x DT(1)]	D	D	D	0	
LR	x [PR x DT(1)]	D	D	D	0	
[OG x DT]	x [PR x DT(1)]	D	D	D	0	16
[PR x DT(2)]	x [PR x DT(1)]	D	D	D	0	
[PR x LR]	x [PR x DT(1)]	D	D	D	0	
LJ	x [PR x DT(1)]	B	C	C	4	
CV	x [PR x DT(1)]	D	D	D	0	
FR	x [PR x DT(1)]	B	C	C	4	
Flirt	x [PR x DT(1)]	D	D	D	0	
E	x [PR x DT(1)]	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 23 Continued

Crosses		Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
AW	x DT	A	C	C	5	
C	x DT	A	C	C	5	
[PR x DT(1)]	x DT	B	C	C	4	
[PR x OG]	x DT	A	C	B	6	
[KR x LR]	x DT	B	C	C	4	
LR	x DT	A	C	C	5	
[OG x DT]	x DT	A	C	C	5	
[PR x DT(2)]	x DT	D	D	D	0	52
[PR x LR]	x DT	B	C	B	5	
LJ	x DT	D	D	D	0	
CV	x DT	B	D	C	3	
FR	x DT	A	C	B	6	
Flirt	x DT	B	C	C	4	
E	x DT	D	D	D	0	
AW	x [PR x OG]	A	C	B	6	
C	x [PR x OG]	B	C	C	4	
[PR x DT(1)]	x [PR x OG]	A	C	C	5	
DT	x [PR x OG]	D	D	D	0	
[KR x LR]	x [PR x OG]	B	C	B	5	
LR	x [PR x OG]	D	D	D	0	
[OG x DT]	x [PR x OG]	A	C	B	6	59
[PR x DT(2)]	x [PR x OG]	A	C	B	6	
[PR x LR]	x [PR x OG]	A	C	B	6	
LJ	x [PR x OG]	A	C	C	5	
CV	x [PR x OG]	A	C	D	4	
FR	x [PR x OG]	B	C	C	4	
Flirt	x [PR x OG]	A	C	C	5	
E	x [PR x OG]	B	C	D	3	
AW	x [KR x LR]	D	D	D	0	
C	x [KR x LR]	A	C	C	5	
[PR x DT(1)]	x [KR x LR]	D	D	D	0	
DT	x [KR x LR]	D	D	D	0	
[PR x OG]	x [KR x LR]	D	D	D	0	
LR	x [KR x LR]	D	D	D	0	
[OG x DT]	x [KR x LR]	D	D	D	0	
[PR x DT(2)]	x [KR x LR]	B	C	C	4	9
[PR x LR]	x [KR x LR]	D	D	D	0	
LJ	x [KR x LR]	D	D	D	0	
CV	x [KR x LR]	D	D	D	0	
FR	x [KR x LR]	D	D	D	0	
Flirt	x [KR x LR]	D	D	D	0	
E	x [KR x LR]	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 23 Continued

Crosses		Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
AW	x LR	D	D	D	0	
C	x LR	D	D	D	0	
[PR x DT(1)]	x LR	D	D	D	0	
DT	x LR	B	C	D	3	
[PR x OG]	x LR	A	C	B	6	
[KR x LR]	x LR	D	D	D	0	
[OG x DT]	x LR	A	C	B	6	
[PR x DT(2)]	x LR	D	D	D	0	25
[PR x LR]	x LR	D	D	D	0	
LJ	x LR	A	C	B	6	
CV	x LR	D	D	D	0	
FR	x LR	B	C	C	4	
Flirt	x LR	D	D	D	0	
E	x LR	D	D	D	0	
AW	x [OG x DT]	B	C	C	4	
C	x [OG x DT]	D	D	D	0	
[PR x DT(1)]	x [OG x DT]	D	D	D	0	
DT	x [OG x DT]	D	D	D	0	
[PR x OG]	x [OG x DT]	A	B	B	7	
[KR x LR]	x [OG x DT]	A	C	C	5	
LR	x [OG x DT]	A	C	C	5	
[PR x DT(2)]	x [OG x DT]	A	C	C	5	41
[PRxLR]	x [OG x DT]	D	D	D	0	
LJ	x [OG x DT]	A	C	C	5	
CV	x [OG x DT]	B	D	D	2	
FR	x [OG x DT]	B	C	C	4	
Flirt	x [OG x DT]	B	C	C	4	
E	x [OG x DT]	D	D	D	0	
AW	x [PR x DT(2)]	D	D	D	0	
C	x [PR x DT(2)]	D	D	D	0	
[PR x DT(1)]	x [PR x DT(2)]	D	D	D	0	
DT	x [PR x DT(2)]	D	D	D	0	
[PR x OG]	x [PR x DT(2)]	A	C	C	5	
[KR x LR]	x [PR x DT(2)]	D	D	D	0	
LR	x [PR x DT(2)]	D	D	D	0	
[OG x DT]	x [PR x DT(2)]	A	C	C	5	19
[PRxLR]	x [PR x DT(2)]	A	C	C	5	
LJ	x [PR x DT(2)]	B	C	C	4	
CV	x [PR x DT(2)]	D	D	D	0	
FR	x [PR x DT(2)]	D	D	D	0	
Flirt	x [PR x DT(2)]	D	D	D	0	
E	x [PR x DT(2)]	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 23 Continued

Crosses		Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
AW	x [PR x LR]	D	D	D	0	
C	x [PR x LR]	B	C	C	4	
[PR x DT(1)]	x [PR x LR]	B	C	C	4	
DT	x [PR x LR]	D	D	D	0	
[PR x OG]	x [PR x LR]	A	C	B	6	
[KR x LR]	x [PR x LR]	B	C	C	4	
LR	x [PR x LR]	D	D	D	0	
[OG x DT]	x [PR x LR]	B	C	C	4	34
[PR x DT(2)]	x [PR x LR]	A	C	C	5	
LJ	x [PR x LR]	A	C	C	5	
CV	x [PR x LR]	B	D	D	2	
FR	x [PR x LR]	D	D	D	0	
Flirt	x [PR x LR]	D	D	D	0	
E	x [PR x LR]	D	D	D	0	
AW	x LJ	B	C	C	4	
C	x LJ	D	D	D	0	
[PR x DT(1)]	x LJ	D	D	D	0	
DT	x LJ	D	D	D	0	
[PR x OG]	x LJ	A	C	C	5	
[KR x LR]	x LJ	B	C	D	3	
LR	x LJ	D	D	D	0	18
[OG x DT]	x LJ	D	D	D	0	
[PR x DT(2)]	x LJ	B	C	C	4	
[PR x LR]	x LJ	D	D	D	0	
CV	x LJ	B	D	D	2	
FR	x LJ	D	D	D	0	
Flirt	x LJ	D	D	D	0	
E	x LJ	D	D	D	0	
AW	x CV	D	D	D	0	
C	x CV	D	D	D	0	
[PR x DT(1)]	x CV	D	D	D	0	
DT	x CV	D	D	D	0	
[PR x OG]	x CV	D	D	D	0	
[KR x LR]	x CV	D	D	D	0	
LR	x CV	D	D	D	0	0
[OG x DT]	x CV	D	D	D	0	
[PR x DT(2)]	x CV	D	D	D	0	
[PRxLR]	x CV	D	D	D	0	
LJ	x CV	D	D	D	0	
FR	x CV	D	D	D	0	
Flirt	x CV	D	D	D	0	
E	x CV	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

Table 23 Continued

Crosses		Fruiting candles (%)	Fruit set (%)	Seed germination (%)	Varietal score	Total score
AW	x FR	D	D	D	0	
C	x FR	D	D	D	0	
[PR x DT(1)]	x FR	B	C	C	4	
DT	x FR	B	C	B	5	
[PR x OG]	x FR	A	C	C	5	
[KR x LR]	x FR	D	D	D	0	
LR	x FR	B	C	B	5	39
[OG x DT]	x FR	B	C	C	4	
[PR x DT(2)]	x FR	A	C	C	5	
[PRxLR]	x FR	A	C	B	6	
LJ	x FR	A	C	C	5	
CV	x FR	D	D	D	0	
Flirt	x FR	D	D	D	0	
E	x FR	D	D	D	0	
AW	x Flirt	D	D	D	0	
C	x Flirt	D	D	D	0	
[PR x DT(1)]	x Flirt	D	D	D	0	
DT	x Flirt	D	D	D	0	
[PR x OG]	x Flirt	B	C	C	4	
[KR x LR]	x Flirt	D	D	D	0	
LR	x Flirt	D	D	D	0	
[OG x DT]	x Flirt	D	D	D	0	
[PR x DT(2)]	x Flirt	D	D	D	0	9
[PRxLR]	x Flirt	A	C	C	5	
LJ	x Flirt	D	D	D	0	
CV	x Flirt	D	D	D	0	
FR	x Flirt	D	D	D	0	
E	x Flirt	D	D	D	0	
AW	x E	D	D	D	0	
C	x E	D	D	D	0	
[PR x DT(1)]	x E	D	D	D	0	
DT	x E	D	D	D	0	
[PR x OG]	x E	D	D	D	0	
[KR x LR]	x E	D	D	D	0	
LR	x E	D	D	D	0	
[OG x DT]	x E	D	D	D	0	0
[PR x DT(2)]	x E	D	D	D	0	
[PRxLR]	x E	D	D	D	0	
LJ	x E	D	D	D	0	
CV	x E	D	D	D	0	
FR	x E	D	D	D	0	
Flirt	x E	D	D	D	0	

A = 3 points, B = 2 points, C = 1 point and D = 0 point

LR, Lady Jane, OG x DT and PR x DT (2) got the high varietal scores. The crosses of the fifteen male parents were linearly scored on the basis of percentage of fruiting candles, fruit set and seed germination as shown in the Table 23. Among male parents PR x OG, DT, OG x DT, FR and PR x LR got the high varietal scores. So PR x OG, OG x DT and PR x LR could be judged as the best male as well as female parents. The highest score for an individual cross was obtained for the crosses (PR x OG) x (OG x DT), (PR x LR) x C, FR x DT, AW x (PR x OG), (OG x DT) x (PR x OG), (PR x LR) x (PR x OG),PR x DT (2) x (PR x OG), (OG x DT) x LR, LJ x LR, (PR x OG) x DT, (PR x OG) x LR, (PR x OG) x (PR x LR) and (PR x LR) x FR. So these were the most compatible crosses. The female parents Esmeralda, Dragon's tongue, and Ceasor Violet showed poor performance. Among the male parents KR x LR and Flirt showed poor performance during the course of study while Esmeralda and Ceasor Violet not produced pollen during the crossing period.

4.2.3 Morphological characters

The mean performance of the seedlings of 57 successful crosses for four morphological characters under the study were worked out and furnished in Table.24

4.2.3.1 Days from emergence to maturity of leaves

The maximum number of days was taken by the cross LJ x (PR x LR) (36.33) followed by [(KR x LR) x (PR x LR)] (35.60), Flirt x (OG x DT) (35.33) and (OG x DT) x (PR x LR) (35.25). The least number of days for maturity of leaves was taken by C x (PR x OG) (23.80) followed by (PR x OG) x FR (25.80) and (PR x OG) x DT (26.40).

4.2.3.2 Number of leaves

Maximum number of leaves was produced by the cross (PR x OG) x (OG x DT) (6.33) followed by (PR x OG) x (PR x LR), (OG x DT) x (PR x OG) and Flirt x (PR x OG) (6.20) while the lowest for the cross DT x FR (4.50) followed by FR x LR and (PR x LR) x AW (4.60).

Table 24 Vegetative character differentiation in seedlings of *A. andreanum*

Combination	Colour of petiole	Colour of young leaf	Number of leaves	Leaf area	Days from emergence to maturity of leaves
AW x C	Greenish brown	Greenish brown	5.60	18.17	29.60
AW x [PR x DT (1)]	Reddish brown	Reddish brown	5.20	17.65	32.33
AW x DT	Green	Reddish brown	5.29	17.24	30.40
AW x (PR x OG)	Greenish brown	Reddish brown	5.44	17.37	27.80
AW x (OG x DT)	Green	Green	5.37	16.79	33.40
C x [PR x DT (1)]	Reddish brown	Reddish brown	5.33	19.13	28.50
C x DT	Greenish brown	Reddish brown	5.50	18.13	27.60
C x (PR x OG)	Brown	Reddish brown	5.22	17.67	23.80
[PR x DT (1)]x DT	Greenish brown	Reddish brown	5.60	17.52	29.40
[PR x DT (1)]x (PR x OG)	Brown	Reddish brown	4.80	16.71	28.80
[PR x DT (1)]x (PR x LR)	Greenish brown	Greenish brown	5.33	17.65	34.20
[PR x DT (1)]x FR	Greenish brown	Reddish brown	4.71	18.00	32.60
DT x FR	Green	Reddish brown	4.50	19.21	32.20
(PR x OG) x AW	Greenish brown	Brown	5.70	16.88	28.60
(PR x OG) x DT	Brown	Brown	5.60	17.13	26.40
(PR x OG) x LR	Reddish brown	Reddish brown	6.18	17.70	26.80
(PR x OG) x (OG x DT)	Greenish brown	Reddish brown	6.33	16.79	27.40
(PR x OG) x [PR x DT (2)]	Greenish brown	Reddish brown	5.80	18.17	27.60
(PR x OG) x (PR x LR)	Greenish brown	Greenish brown	6.20	17.82	26.50
(PR x OG) x FR	Greenish brown	Greenish brown	5.20	17.37	25.80

Table 24 Continued

Combination	Colour of petiole	Colour of young leaf	Number of leaves	Leaf area	Days from emergence to maturity of leaves
(KR x LR) x AW	Greenish brown	Greenish brown	5.27	18.17	34.00
(KR x LR) x DT	Greenish brown	Reddish brown	4.76	17.41	33.60
(KR x LR) x (PR x OG)	Brown	Reddish brown	6.00	15.93	30.40
(KR x LR) x (OG x DT)	Greenish brown	Greenish brown	5.80	17.14	34.80
(KR x LR) x (PR x LR)	Greenish brown	Greenish brown	5.50	17.70	35.60
LR x DT	Greenish brown	Greenish brown	4.80	19.64	30.80
LR x (OG x DT)	Greenish brown	Greenish brown	5.60	18.86	29.60
LR x FR	Greenish brown	Greenish brown	5.40	21.05	28.60
(OG x DT) x DT	Green	Greenish brown	4.80	18.31	32.20
(OG x DT) x (PR x OG)	Greenish brown	Greenish brown	6.20	16.73	27.60
(OG x DT) x LR	Greenish brown	Greenish brown	5.80	19.00	32.20
(OG x DT) x [PR x DT (2)]	Green	Green	5.20	19.51	33.60
(OG x DT) x (PR x LR)	Green	Green	4.80	19.90	35.25
(OG x DT) x FR	Green	Greenish brown	5.27	19.21	29.50
[PR x DT (2)] x(PR x OG)	Brown	Greenish brown	5.80	16.15	30.80
[PR x DT (2)] x (OG x DT)	Greenish brown	Green	5.20	18.67	34.20
[PR x DT (2)] x (PR x LR)	Greenish brown	Green	4.80	18.94	33.60
[PR x DT (2)] x FR	Greenish brown	Green	4.80	18.35	31.80
(PR x LR) x AW	Green	Green	4.60	19.92	34.20
(PR x LR) x C	Greenish brown	Greenish brown	5.20	20.28	28.80
(PR x LR) x DT	Green	Greenish brown	4.67	20.67	33.40

Table 24 Continued

Combination	Colour of petiole	Colour of young leaf	Number of leaves	Leaf area	Days from emergence to maturity of leaves
(PR x LR) x (PR x OG)	Greenish brown	Greenish brown	5.40	17.37	29.40
(PR x LR) x [PR x DT (2)]	Greenish brown	Green	5.20	19.96	34.20
(PR x LR) x FR	Green	Green	4.80	19.55	31.60
LJ x (PR x OG)	Greenish brown	Greenish brown	4.80	15.16	33.20
LJ x LR	Greenish brown	Greenish brown	4.71	15.93	34.00
LJ x (PR x LR)	Green	Green	4.67	16.13	36.33
CV x (PR x OG)	Greenish brown	Reddish brown	5.40	16.44	28.40
FR x [PR x DT (1)]	Greenish brown	Greenish brown	5.60	17.82	29.60
FR x DT	Green	Brown	5.20	19.37	29.20
FR x(PR x OG)	Greenish brown	Reddish brown	6.00	17.31	28.80
FR x LR	Greenish brown	Reddish brown	4.60	19.74	26.80
FR x (OG x DT)	Green	Greenish brown	5.11	19.13	29.40
Flirt x AW	Greenish brown	Greenish brown	4.75	16.25	34.25
Flirt x DT	Greenish brown	Brown	5.50	16.13	33.50
Flirt x (PR x OG)	Brown	Reddish brown	6.20	15.67	30.60
Flirt x (OG x DT)	Greenish brown	Greenish brown	5.33	16.41	35.33

4.2.3.3 Leaf area (cm^2)

The leaf area was maximum for the cross LR x FR (21.05 cm^2) followed by (PR x LR) x DT (20.67 cm^2) and (PR x LR) x C (20.28 cm^2). The minimum leaf area observed for the cross LJ x (PR x OG) (15.16 cm^2).

4.2.3.4 Colour of young leaf and petiole

The colour of young leaf showed a range from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green.

Discussion

5. DISCUSSION

The cultivation of anthurium especially *Anthurium andreanum* Linden for cut flowers has assumed greater importance in recent times, owing to the premium prices it fetches both in domestic and international markets. Mostly unnamed types of anthurium based on spathe colour are cultivated in India.

Basic information on the breeding behaviour of this crop to improve the existing types and varieties are lacking. Anthuriums are commercially propagated now by tissue culture. But in hybridization programme the seed progenies are raised. In the present study an attempt is made to improve the commercial characters through hybridization. Variability is statistically analysed along with cross compatibility studies and the results are discussed below.

5.1 MEAN PERFOMANCE

All the 40 genotypes studied showed wide variations for all the quantitative and qualitative characters. They showed significant variation in plant height ranging from 17.33 cm in Nitta Orange to 43.25 cm in Liver Red. The mean plant height observed was 28.51 cm. The heights of varieties PR x DT (2) (41.33 cm), PR x DT (1) (39.22 cm), PR x LR (39 cm) and OG x DT (37.66 cm) were high and on par with Liver Red (43.25 cm).

Abdussammed (1999) has reported that nutrients significantly influenced the plant height, both in ground as well as pot planting. But plant height can be considered as a varietal character, as reported by Bindu and Mercy (1994). They reported significant variations for plant height in the five varieties. The six varieties studied by Sindhu (1995) also recorded significant variation in height.

Renu (2000) recorded significant variation in plant height ranging from 29.70 cm to 70.90 cm. According to Mayadevi (2001) the plant height ranged from 42.50 cm in Midori Green to 96.67 cm in Ordinary White. The plant height ranged from 22.17 cm to 64.80 cm among the fifty genotypes studied by Asish

(2002). Premna (2003) observed a plant height of 21.25 cm ('Carre') to 44.00 cm ('PR x DT'). The six varieties studied by Talia et al, (2003) and Cristiano et al, (2007) also recorded significant variations in plant height. Pravin (2004) in a study with 14 genotypes of anthurium found significant variations in plant height and it ranged from 30.80 cm to 76.17 cm. According to Shiva and Nair (2008 b) the plant height ranged from 4.27 cm in Taurus to 9.22 cm in Mirage.

Leaf area varied according to the size of the leaf. In the present study leaf area ranged from 58.62 cm^2 in Rembolina (Pink and Green) to 343.56 cm^2 in PR x DT (1). Mercy and Dale (1994) reported that leaves of commercially valuable floral anthuriums should be small to medium sized, narrow and elongated. Large and exuberantly growing leaves are undesirable. Salvi (1997) observed that with decline in shade intensity, leaf area also decreased significantly. Mayadevi (2001) reported that variety Chilli Red had the leaf area of 66.26 cm^2 followed by variety Kalympong Red 66.92 cm^2. Asish (2002) in his study with fifty genotypes observed that most of the genotypes had a medium leaf area in between 92.20 to 183.40 cm^2. Premna (2003) noticed that the leaf area ranged from 113.62 to 301.10 cm^2 in fourteen genotypes. Pravin (2004) observed leaf area varied according to the size of the leaf and it was ranged from 91.97 cm^2 in PR x FR (1) to 287.76 cm^2 in LR x PR. Shiva and Nair (2008 b) reported that the mean leaf size range from 2.95 to5.36 cm while leaf area ranged from 5.33 to 16.43 cm^2.

The mean internode length in the present study ranged from 0.97 cm in Agnihotri to 2.02 cm in Esmeralda. Plants with short internodes which give the plant a compact appearance are preferred (Mercy and Dale, 1994). According to Singh (1987), a desirable anthurium should produce short internodes which limit the height of the plant. Mayadevi (2001) reported that the mean internode length among the hybrids ranged from 1.02 to 1.34 cm and in five parents it ranged from 1.00 to 1.52 cm. Asish (2002) observed an average internode length of 1.56 cm and Premna (2003) recorded an internode length of 1.20 to 1.48 cm. Pravin, (2004) in his study with fourteen genotypes observed that the mean internode length was 1.20 cm with a range of 0.93 cm in MO x KR (1) to 1.63 in LR x PR.

Though propagation of anthuriums using suckers is a very slow but good process, so suckering is an important trait considered in the selection of superior genotypes. The present investigation revealed that suckering was very high for Liver Red (3); low for Lady Jane and Esmeralda (0.67) and nil for half of the genotypes. Mercy and Dale (1994) opined that most of the good commercial *Anthurium* varieties were very shy suckering or did not sucker at all. They recommended the use of Gibberellic acid (GA) or Benzyl adenine (BA) (500 – 1000 ppm) to increase the rate of sucker production. This indicates influence of hormones on suckering. Similar effect of growth regulators on sucker production had been reported by Higaki and Rasmussen (1979), Salvi (1997) and Abdussammed (1999).

Mayadevi (2001) observed maximum number of sucker production (4) for the varieties Pink, Lady Jane and the least number of sucker for the varieties Nitta Orange, Merengue White and Tropical Red. In the study by Asish (2002) most of the genotypes (64 per cent) had suckers with a range of 1.37 to 2.46 which comes under medium suckering types. Premna (2003) noticed maximum sucker production in OO x KR (2.25) and lowest in Acropolis White (0.25). Pravin, (2004) reported that among the varieties studied suckering was very high for Liver Red (4), low for KO x CR and PR x KR and nil for FR x MW (1), Acropolis White and Tropical Red. Shiva and Nair, (2008 b) observed maximum number of suckers in Mirage.

The present investigation revealed that one spadix each was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant was the same. The annual production of leaves or spadices was highest in Rembolina (Pink and Green) (7.42) followed by Grace (White) (7.37) and PR x OG (7.05). The lowest number of 4.55 was recorded by Chocos. Similar close correlation between the number of leaves and the number of spadices was observed by Gajek and Schwarz (1980). Steen and Vijverberg (1973) compared the productivity of 120 individual anthurium plants and found that it ranged between four to sixteen spadices over the two years. According to

Mayadevi (2001) generally a single spadix was found to be produced from the axil of each leaf so that the number of leaves and number of spadices produced annually were equal. As it takes more than a month to produce a new leaf or a new flower and with a leaf flower leaf pattern. Mercy and Dale (1994) recorded the annual production of spadices as five to eight while Sindhu (1995) recorded it as four to eight. Mayadevi (2001) reported that average production ranged from 4.67 to 8.00. Asish (2002) observed that, among 50 genotypes he studied maximum number was observed in KO x DT (7) while the minimum in 'PR x DT' and 'TR x MW (3)'.

Premna (2003) observed the maximum number of spadices in the genotypes 'Acropolis White', 'OO x PR', 'PR x DT' and 'Tropical Red' (6) and minimum number in the variety 'Carre' (4.25). Talia et al, (2003) recorded it as 4.6 to 7.3. Pravin (2004) revealed that one spadix each was produced from the axil of each leaf so that the number of leaves and number of spadices produced annually per plant was the same. The annual production of leaves or spadices ranged from 4.67 to 7.00. The present study was in confirmation with the above reports.

In the present study the days from emergence to maturity of leaves ranged from 25.89 days in PR x OG to 36.6 days in Agnihotri. Mayadevi (2001) recorded that the variety Honeymoon Red took 41.40 days and for variety Pink it was 44.40 days for maturity of leaves. Asish (2002) with 50 genotypes observed the average days for the emergence of leaves to its maturity as 27.56 with a range 15.33 days in OG x LR to 41.00 days in DT x FR. Premna (2003) noticed the least number of days for maturity of leaves for Carre (26.25) and a maximum number for PR x DT (40.25). Pravin (2004) recorded the days from emergence to maturity of leaves ranged from 26.57 days in NO x DT to 35.67 days in Tropical Red. The observations in the present study are in confirmation with these reports.

The observations on the days from emergence to maturity of inflorescence in the present study ranged from 23.83 days in Grace (white) to 33.39 days in

Liver Red. Mayadevi (2001) observed that the days from emergence to maturity of inflorescence ranged from 44.60 days in 'Chilli Red' to 50.60 days in 'Honeymoon Red' among the parents while the range of this character in the hybrids was from 41 days in 'HR x P' to 54 days in 'HR x KR'. Asish (2002) in his study observed that this character ranged from 16.67 days in 'NO x LR (1)' to 37.67 days in 'MO x KR (1)'. Premna (2003) recorded the lowest mean value for the variety 'Carre' (29.00 days). Pravin (2004) reported that the days from emergence to maturity of Inflorescence ranged from 31.00 days in KO x CR to 37.20 days in FR x MW (1). Shiva and Nair (2008 b) observed that the cultivars, Mauritius and Wrinkled Orange, took minimum time for flowering from flower initiation.

In the present study the mean Spathe size (cm^2) ranged from 24.44 cm^2 in W x LJ to 123.43 cm^2 in Acropolis White. In a study with 100 different genotypes of anthurium, Maya Devi (2001) observed average spathe length was 10.80 cm with a range of 6.33 cm to 21.33 cm and width of spathe had an average of 7.76 cm. The width ranged from 4.27 cm to 13 cm. Praneetha et al (2002) observed the maximum values for spathe length and width as 16.3 cm and 13.4 cm respectively. Talia et al, (2003) reported that Queen showed a bigger spathe with a mean length of 23 cm and a mean width of 18 cm, whereas Santè exhibited the smallest spathe (10 cm for both parameters, on average). Cristiano et al, (2007) observed that Premier showed a bigger spathe with a mean length of 23 cm and a mean width of 20 cm. Shiva and Nair (2008 b) observed that the spathe size ranged from 5.8 to 8.52 cm.

Anthocyanins contribute various colours to spathe from deep maroon to light pink. In the present study the total anthocyanin content showed wide variation among the genotypes and it was ranged from 9.73 mg/g in W x LJ to 482.05 mg/g in PR x LR. Mayadevi (2001) reported that mean total anthocyanin content ranged from 121.38 mg/g in Pink to 386.56 mg/g in Liver Red in the parents while the range of this character was from 146.03 mg/g (Honeymoon Red x Liver Red) to 330.95 mg/g (KR x CR) in the hybrids. Asish (2002) in his study

with 50 genotypes reported that the mean total anthocyanin content ranged from 26.81 mg/g in the genotype FR x KR to 710.79 mg/g in the genotype PR x LR (3). Premna (2003) reported that the mean anthocyanin content ranged from 10.09 mg/g in Acropolis White to 259.18 mg/g in Honduras. The present study was in confirmation with the above reports.

Short and slender candle is a desirable feature for *Anthurium* flowers. In the present investigation the genotypes LR x PR (3.27 cm), Grace (white) (3.35 cm) and Orange Glory (3.58 cm) had short candles and OG x DT (8.77 cm), PR x DT (1) (8.38 cm) and Lady Jane (8.06 cm) had longer candles which is not ideal. Mercy and Dale (1994) reported that the candle was long and fleshy in ordinary non commercial varieties, and it was shorter and more slender in hybrids. The five varieties studied by Bindu and Mercy (1994) showed a candle length range of 4.0 cm to 9.5 cm. The candle length of six varieties studied by Sindhu (1995) ranged from 6.60 cm to 12.10 cm. According to Mayadevi (2001) the variety Pink had longest candle (12.72 cm) and the variety Liver Red (7.18 cm) had shortest candle. Asish (2002) observed that the genotype FR x MW (2) had the minimum candle length of 3.13 cm while FR x MW (1) had maximum candle length of 9.17 cm. Premna (2003) observed shorter candle in the genotypes FR x KR (4.63 m), LR x FR (4.75 cm) and Carre (4.88 cm). Pravin, (2004) reported that the genotypes MO x KR (1) (3.83 cm) and PR x FR (1) (4.97 cm) had short candles and PR x MO and LR x PR had longer candles (8.00 cm and 7.83 cm) which is not ideal. Srinivasa and Reddy (2005) recorded maximum spadix length and girth of 6.57 cm and 7.93 mm respectively. Shiva and Nair, (2008 b) observed maximum spadix length in the cultivar Colarado.

Mercy and Dale (1994) recommended that ideal *Anthurium* varieties should have a short candle, curving towards the tip of the spathe and held at an angle less than 45^0. Such ideal position of candle was observed in Orange Glory (35.33^0), TR x MW (35.83^0) and Pompon Red (37.5^0). The genotype Grace (white), showed an angle of 75.67^0 which was not desirable. In a similar study Sindhu (1995) found that the varieties with ideal position of candles were Chilli

Red, Kalympong Orange, Kalympong Red and White. Mayadevi (2001) noticed that the inclination of candle ranged from 21^0 to 78.20^0 among the parents and from 20.80^0 to 89.60^0 among the hybrids. Asish (2002) in his study of 50 genotypes reported that more than 50 per cent of the genotypes had an angle less than 45^0. Premna (2003) reported the lowest angle for the genotype 'KR x LR' (21°) which was on par with 'PR x FR' (22.5°). Pravin (2004) reported that among the 14 genotypes PR x MO had the minimum angle of 26.10° while MO x KR (1) had the maximum angle of 70.07°.

The larger the candle the more number of flowers per candle. Though varieties like 'Honeymoon Red' and 'Pink' have large candles with flowers upto 400 or more, they are not preferred as these varieties are non-commercial. Ideal commercial varieties have smaller candles with less number of flowers. In the present study the number of flowers /spadix ranged from 196 in LR x PR and Corolix (Red and Green) to 518.67 in KR x LR. Sindhu (1995) observed that the average number of flowers produced were maximum in 'Pink' and 'Honeymoon Red' (325 flowers) and lowest in the variety 'Chilli Red' (175 flowers). Renu (2000) found that number of flowers per candle varied from variety to variety, which ranged from 254 in 'Tropical Red' to 450 in 'Lady Jane Red'. Mayadevi (2001) recorded that the number of flowers per candle ranged from 372 in 'Chilli Red' to 600 in 'Pink' among the parents and it ranged from 400 to 600 among the hybrids.

According to Paull (1982), the non reversible visible changes accompanying the senescence of *Anthurium* spadices were, loss of spathe-gloss, necrosis of spadix and greening of spathe and spadix. Mercy and Dale (1994) also noticed that senescence was marked by yellowing of peduncle and withering of spathe and candle, which took nearly 4 to 7 months from the emergence of young spadix. In the present study, the time span from the emergence of a spadix to its senescence varied from 46.83 days in Gold Spark to 101.33 days in PR x DT (1) in the case of unfertilized spadices. OG x DT (97.72 days), Acropolis white (96.17 days) and Liver Red (93.83 days) recorded high mean life of the spadix

which were on par with PR x DT (1) (101.33 days). Sindhu (1995) reported that the life of unfertilized spadix was about 1.5 to 3.5 months, while in fertilized spadices it varied from 4.5 to 8.0 months. Mayadevi (2001) in her study reported that it varied from 98 days in Chilli Red to 120.40 days in Honeymoon Red among parents, and in hybrids, it ranged widely from 110.80 days in LR x KR to 126.00 days in HR x KR. Similar results were obtained by Premna (2003) also, who reported that the life of the unfertilized spadix was about 59.5 to 101.5 days. Shiva and Nair, (2008) found that the shelf-life of flower on the plant was found to be longest in Wrinkled Orange followed by Honey.

Initiation of female phase was identified by honeydew secretion on the projected stigmas. Studies by Mercy and Dale (1994) revealed that, in *Anthurium* species flower maturation started from the basal portion and proceeded regularly towards the apex. They listed many protogynous species of *Anthurium*, in which *Anthurium andreanum* was included. However, Later studies by Bindu and Mercy (1994), Sindhu (1995) and Renu (2000) also revealed the protogynous nature of Anthurium *andreanum* varieties. Observations in the present study also highlighted the clear protogynous nature of this species. The number of days required for visible initiation of female phase was observed to vary from 3.55 days in Lady Jane to 10.55 days in Boroque. Initiation of female phase was identified by the slight projection by stigmas and presence of viscous exudate on the candle. Sindhu (1995) also reported that the days to initiation of female phase ranged within a period upto ten days, with the variety Honeymoon Red showing the longest period among the six varieties studied by her. Renu (2000) observed longest period in Mauritius Orange and shortest in Lady Jane Red. Mayadevi (2001) noticed that the initiation of female phase ranged from 4.40 days among the parents to 6.80 days among the hybrids. Observation by Asish (2002) and Premna (2003) revealed the same results. Pravin (2004) observed that the initiation of female phase ranged from 4.33 days in PR x MO to 9.27 days in PR x FR (1).

The interphase between the female and male phase was marked by the drying up of stigmatic droplets. Observation from the forty varieties in the present study showed that the interphase ranged from 3.55 days in Vezuvious Red to 9.22 days in Nitta Orange on an average. Almost similar observations was recorded by Bindu and Mercy (1994) who reported that the interphase lasted for about four to seven days. The variety Acropolis White had the longest interphase period and the shortest was in NO x DT. (Days of interphase and male phase could not be recorded for the varieties LR x DT, FR x MW (1), KO x CR and PR x MO in which no pollen production was observed during the period of this study). Croat (1980) observed that the duration of interphase was several days in most *Anthurium* species, whereas in a few of them the time lag was so short that it was not certain whether those species were homogamous or protogynous. Sindhu (1995) with six varieties noticed that interphase lasted for four to ten days. Asish (2002), Premna (2003) recorded that interphase ranged from 2.00 days to 9.20 days. Pravin (2004) observed that the interphase ranged from 2.33 to 6.83 days.

Following the interphase, a male phase was observed, marked by anther extrusion from the base of the candle and proceeding upwards. In the present study the average number of days for which the candles remained in male phase ranged from 3.37 days in Corolix (Red and Green) to 10.89 days in TR x MW. The genotypes PR x DT (1) (10.47 days), Acropolis white (10.36 days), Jewel and Arun Gold (10.33 days) recorded high duration of male phase which were on par with TR x MW. A very similar report was that of Bindu and Mercy (1994) who reported that the male phase lasted for 3 to 7 days. Croat (1980) reported that in some *Anthurium* species the male phase lasted for several weeks and that anther emergence may be scattered as in *A. caperatum* or sporadic as in *A. luteynii.* Similar scattered anther emergence on the candle was observed in the varieties Liver Red and Orange Glory under the present study. In the variety Acropolis White sometimes only a portion of the candle showed anther emergence such observations were recorded by Sindhu (1995) also in the variety Kalympong Red. Asish (2002) and Premna (2003) recorded that the male phase may last for 4 to 12

days. Pravin (2004) reported that the average number of days for which the candles remained in male phase ranged from 5.33 days [PR x FR (1)] to 10.83 days (Acropolis White).

The acetocarmine staining method was used to find the pollen fertility of the selected varieties. In the present study the highest pollen fertility was observed for Liver Red (43.01 per cent) followed by Lady Jane (36.14 per cent). Diva pink (2.59 per cent), Corolix (Red and Green) (2.95 per cent), Grace (white) (3.41per cent), Elan red (4.49 per cent), Rembolina (Pink and Green) (4.58 per cent), Flirt (4.94 per cent) and Jewel (5.89 per cent) recorded the lowest pollen fertility values. Mitu and Acatrinei (1974) reported that the germination of pollen grain was proportional to pollen grain stainability as acetocarmine preferentially stains the chromosome or nucleus. The observation by Lalithambika (1978) that the pollen fertility of *A. andreanum* vary from 25 to 30 per cent, is in confirmity with the results of present study. Mercy and Dale (1994) reported that the pollen fertility in *A. andreanum* vary from 20.40 per cent to 28.80 per cent, which again substantiates the present finding. As sterility is a condition frequently associated with hybridity, we can take the low pollen fertility in this crop as an indication of its hybrid nature. Based on the cytological studies of five varieties Bindu and Mercy (1994) concluded that low fertility can also be due to high degree of meiotic abnormalities like clumping, lagging of chromosomes at anaphase, unequal segregation, precocious disjunction of chromosomes, chromosome elimination through micronuclei etc., found in *A. andreanum*. Asish (2002) and Premna (2003) recorded a pollen fertility range of 9.26 to 50.80 percentage. Pravin (2004) reported that most of the genotypes had low fertility values. 'PR x FR (1)' had the highest pollen fertility of 41.67 per cent followed by 'Liver Red' (40.67 per cent).

In the present study the mean size of the pollen ranged from 14.67 in Arun Gold to 25.18 in Lady Jane. Pollen shape ranged from round to oval and majority of the genotypes had round pollen. Bindu (1992) while studying pollen grains of five varieties observed that the size of pollen grains varied from 87.2 x 86.4 μ

(Lady Jane) to 81.8 x 68.0 μ (Pink). All the varieties had more or less round pollen with a germ pore. Premna (2003) recorded a pollen fertility range of 9.26 to 50.80 per cent. Pollen size was found to vary from 16.80 μ in OG x DT to 24.97μ and noticed that the size of pollen grain among the varieties did not vary significantly. Pravin (2004) noticed that the pollen size ranged from 16.80μ in MO x KR (1) to 24.97μ in Liver Red.

A study of five qualitative traits such as colour of young leaf and petiole, spathe colour, spathe texture, candle colour and type of inflorescence axis revealed slight variations. The colour of young leaf showed a range from brown to reddish brown to grenish brown to green to light green. The colour of petiole also varied from brown to reddish brown to greenish brown to green. Mercy and Dale (1994) also observed that the colour of young leaves varied from deep reddish brown to light green. According to Sindhu (1995) it ranged from purple to green and that of young leaves from light green to brown. Premna (2003) in her study with 40 genotypes observed a colour range for the young leaves from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green. Pravin (2004) revealed the same results.

Genetics of spathe colour inheritance was studied in detail by Kamemoto *et al.* (1988). They concluded that two major genes, M and O were responsible for the five major colours: red, orange, pink, coral and white. The gene M was found to control the production of cyanidin-3-rutinoside while O controlled that of pelargonidin-3-rutinoside. Red and pink resulted when both M and O are present. So the red and pink spathed varieties under the present study have both M and O genes. But the variation in red spathe colour from maroon to dark red to bright red to red and pink was explained by their findings that, the incremental effects of M appeared to be greater than that of O and therefore the intensity of colour decreased from MMOO, MMOo, MmOO to MmOo. They have also concluded that orange have a genotype of mmOO and was true breeding while mmOo

expressed a light orange shade called coral. The recessive oo is epistatic to M and white colour resulted when both are recessive (mmoo) or M was in combination with oo (MMoo, Mmoo). Wannakrairoj and Kamemoto (1990) studied the inheritance of purple spathe in anthurium and proposed a scheme to explain this. A recessive allele p, was found to modify the colour of anthocyanins controlled by M and O loci. The spathe was purple when the genotype was M_O_pp. The dominant P allele had no effect on colour in any combinations. The colour genotypes and their phenotypes are as follows.

MMOO
MmOO = Reds
MMOo

MmOo = Pink

mmOO = Orange

mmOo = Coral

MMoo
Mmoo = White
mmoo

M-O-pp = Purple

In the present study the colour of the spathe showed variation like deep maroon, maroon, dark red, medium red, red, dark orange, orange, light orange, pink, white, green, violet, brown and some spathe with two colours (obaki) is in confirmation with above reports. Renu (2000) grouped the spathe colour of 10 varieties into deep maroon to dark red, red, light orange, light orange to dark orange, light green and white. Mayadevi (2001) inferred that anthocyanins contribute various colours to spathe from deep maroon to light pink.

Asish (2002) in his study on 50 genotypes found that the spathe colour range was deep maroon, maroon, dark red, red, light red, dark orange, pink and white. The spathe colour ranged from deep maroon to white in the 14 genotypes observed by Premna (2003). Pravin (2004) grouped the spathe colour of 14 genotypes into deep maroon, dark red, Red, pink, light pink, orange and dark orange.

Spathe texture showed wide variations among the 40 genotypes studied, from thick smooth glossy to thick medium blistered glossy to medium thick medium blistered glossy to medium thick slightly blistered glossy to thick slightly blistered glossy to medium thick slightly blistered nonglossy to thin slightly blistered glossy to medium thick slightly blistered nonglossy spathes. According Birdsey (1956) Linden described the spathe *A. andreanum* based on varying degrees of smoothness and blistering. Mercy and Dale (1994) opined that the spathe of floral anthuriums may be smooth, thick and glossy without prominent veins or it may be thinner deeply veined and blistered. The six varieties studied by Sindhu (1995) also showed variation from thick to thin and deep to shallowly blistered spathe. Renu (2000) noticed that the spathe texture showed high variation among the 10 varieties from thick and deeply blistered in Mauritius Orange to thin and smooth in Lady Jane Red. In the studies by Mayadevi (2001), Asish (2002), Premna (2003) and Pravin (2004) also spathe texture varied from blistered glossy to medium thick deeply blistered glossy to thick smooth glossy to medium thick smooth.

The candle colour showed variation like pink, light yellow, yellow and maroon, yellowish white, creamish white and greenish yellow. According to Mercy and Dale (1994), the candle had a single colour red, pink or green in ordinary anthurium varieties and hybrids had yellow, white, pink or red colours in two or more bands. Sindhu (1995) reported that the six varieties studied had candles with either a single colour or two or more bands of colours. Henny (1999) observed that the anthurium hybrid Red Hot had a candle which was orange red apically blending to red basally. The candle colour of pink to light pink, yellow to yellowish white to red and green was observed by Mayadevi

(2001). Asish (2002), Premna (2003) and Pravin (2004) also observed a colour range from red to light red to reddish pink to pink to light pink to pinkish yellow to yellowish white to cream.

The nature of inflorescence axis is one of the important factors that determine the appearance and hence the value of anthurium flowers when marketed as cut flower. Mercy and Dale (1994) suggested that good anthurium hybrids should have strong and straight inflorescence axis. Type of Inflorescence axis showed variations like long thick straight, long thin straight, long thick curved, long thin curved, medium thick straight, medium thick curved, medium thin curved, short thick straight, short thin straight, short thick curved and short thin curved in the present study. Among the 40 genotypes studied straight and strong inflorescence axis which is more desirable was seen for Acropolis White, Carrie, PR x OG, KR x LR, Liver Red and Pompon Red. According to Mayadevi (2001) inflorescence axis varied from long straight and very strong in all the parents and hybrids except for the parent variety Kalympong Red on which it is long thin and slightly curved which is not desirable.

Asish (2002) reported that long straight and strong inflorescence axis which is most desirable was exhibited by the genotypes 'NO x TR', 'MW x PR', 'TR x MW', 'PR x MW' and 'PR x LR (3)'. Premna (2003) observed long, straight and strong inflorescence axis in 'Acropolis White' and 'Tropical Red'. Pravin (2004) observed straight and strong inflorescence axis in Liver Red, Orange Glory, Acropolis White and Tropical Red.

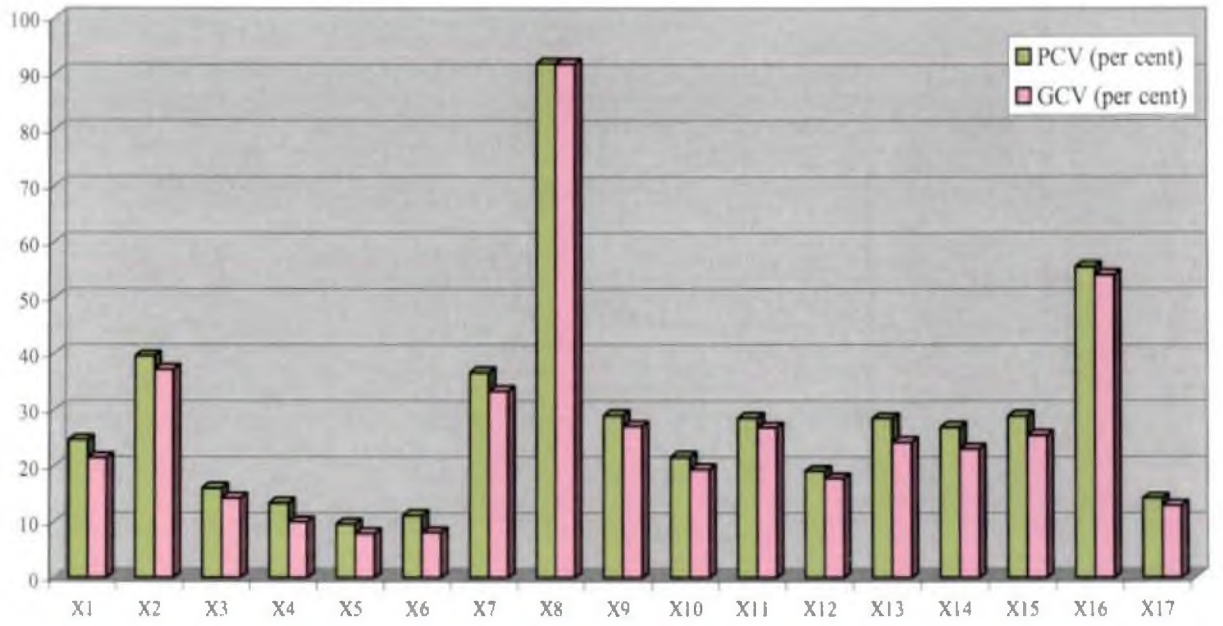
5.2 VARIABILITY COMPONENTS

The magnitude of variability present in a crop species is of great importance as it provides the basis for effective selection. Since, the observed variability in a population is the sum of variation arising due to genotypes and environmental effects, knowledge of genetic variation contributing to genetic gain under selection is essential (Allard, 1960).

Phenotypic and genotypic coefficients of variation were estimated based on the coefficients of variation and these parameters were used to compare the variability among the forty genotypes. GCV is a better tool to understand useful variability, as it is free from the environmental component affecting variability. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variation. GCV and PCV are better indices for comparison of characters with different units of measurement, than estimates of quantitative variation like range and variation around mean.

A perusal of Table.4 shows that high PCV combined with high GCV were obtained for anthocyanin content, pollen fertility, leaf size/leaf area, Spathe size and spadix length. This revealed a great extent of variability for these characters, thereby suggesting good scope for improvement of these important characters through selection. Anthocyanin content recorded highest GCV and PCV. Lower values of GCV and PCV were estimated for the characters days from emergence to maturity of leaves, days from emergence to maturity of inflorescence and number of spadices per plant indicating low magnitude of variability. So, improvement of these characters has only a limited scope (Fig.1).

High PCV and GCV for anthocyanin content observed in this study is supported by similar findings of Asish et al (2003) and Premna (2003). PCV and GCV for pollen fertility high in the present study were supported by the findings of Asish et al (2003) and Pravin (2004). In the present study leaf size/leaf area and spathe size also had high estimates of PCV and GCV. Similar results were reported by Renu (2000) and Maya Devi (2001) for Leaf area and spathe size respectively. Lower values of GCV and PCV were estimated for the days from emergence to maturity of inflorescence in this study was supported by similar findings of Asish et al (2003) and Pravin (2004). Similarly, low PCV and GCV for number of spadices per plant in this study were supported by Maya Devi (2001) and Asish et al (2003).



X_1 Plant height (cm)

X_2 Leaf size/leaf area (cm^2)

X_3 Internodal length (cm)

X_4 Number of leaves per plant

X_5 Days from emergence to maturity of leaves

X_6 Days from emergence to maturity of inflorescence

X_7 Spathe size (cm^2)

X_8 Total Anthocyanin content (mg/g)

X_9 Spadix length (cm)

X_{10} Inclination of candle with the spathe (degrees)

X_{11} Number of flowers/Spadix

X_{12} Life of spadix (days)

X_{13} Days to initiation of female phase

X_{14} Duration of interphase

X_{15} Duration of male phase

X_{16} Pollen fertility (per cent)

X_{17} Pollen size (μ)

Fig. 1 GCV and PCV for the seventeen characters in *Anthurium andreanum*

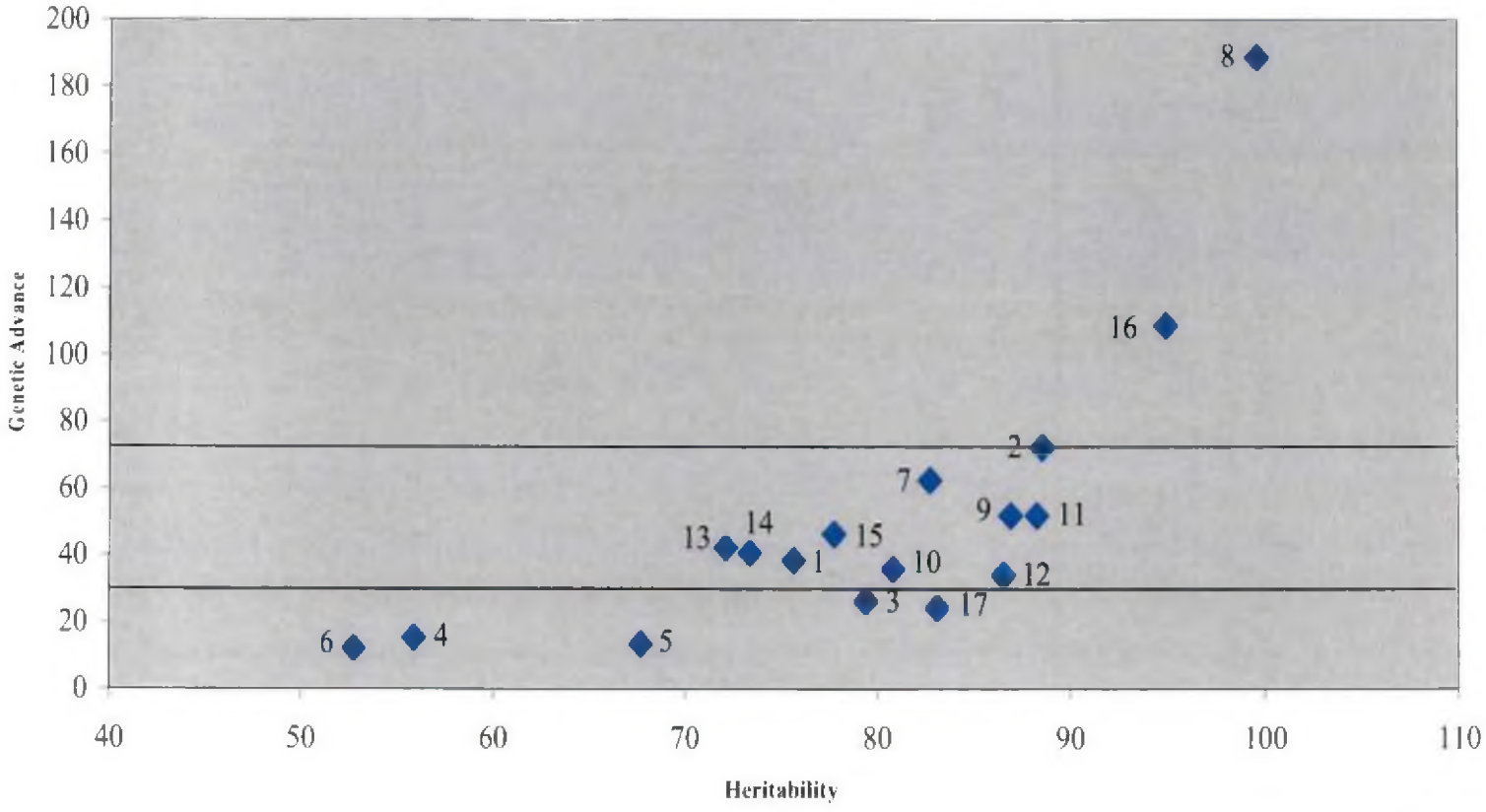
The characters days to initiation of female phase, duration of interphase, duration of male phase, number of leaves per plant, spathe size and plant height showed maximum differences between GCV and PCV which indicates that the influence of environment on these characters is considerable. But the low differences between GCV and PCV for the characters total anthocyanin content, pollen size, life of spadix and pollen fertility pointed out that the variation observed in these characters are mainly due to genetic reasons and environmental influence on these characters was less.

5.3 HERITABILITY AND GENETIC ADVANCE

Heritability estimates the transmissibility of character from one generation to other and it provides a measure of the value of selection for different attributes. But heritability does not necessarily mean a high genetic advance for a particular character (Allard, 1960). Heritability along with genetic advance is more useful than heritability alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955). Fig.2 shows the distribution of characters in terms of heritability (H^2) and genetic advance (GA).

The characters plant height, leaf size/leaf area, internodal length, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size recorded high heritability and genetic advance. High heritability and genetic advance indicates that the character is controlled by additive gene action suggesting the possibility of genetic improvement of those characters through selection (Panse and Sukhatme, 1967).

According to Allard (1960) classification, all the characters except for the characters number of leaves/ spadices per plant and days from emergence to maturity of inflorescence showed high heritability. So selection of phenotypically superior plants with respect to these characters will result in significant improvement in the next generation.



1	Plant height (cm)	7	Spathe size (cm^2)	13	Days to initiation of female phase
2	Leaf size/leaf area (cm^2)	8	Total Anthocyanin content (mg/g)	14	Duration of interphase
3	Internodal length (cm)	9	Spadix length (cm)	15	Duration of male phase
4	Number of leaves per plant	10	Inclination of candle with the spathe (degrees)	16	Pollen fertility (per cent)
5	Days from emergence to maturity of leaves	11	Number of flowers/Spadix	17	Pollen size (μ)
6	Days from emergence to maturity of inflorescence	12	Life of spadix (days)		

Fig. 2 Heritability and genetic advance as percentage of mean for different characters

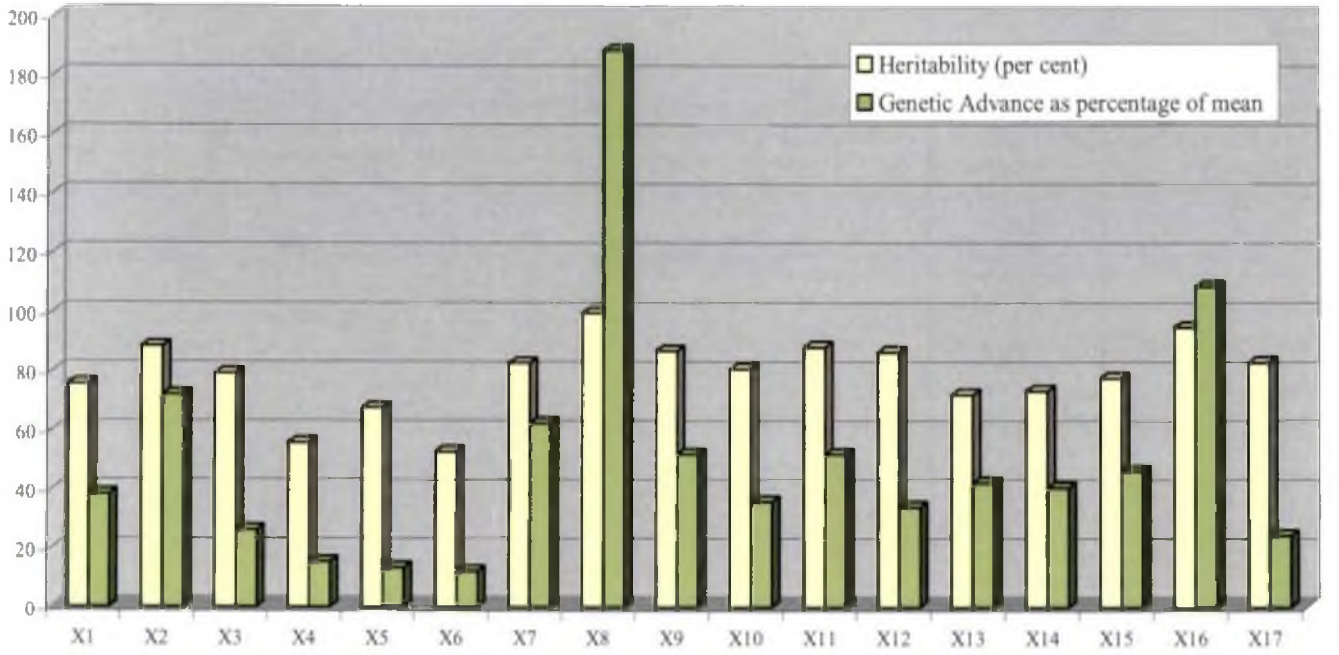
If five per cent selection is to be practiced maximum genetic advance is expected for total anthocyanin content and minimum for internode length. Robinson *et al.* (1949) classified genetic advance as percentage of mean into low (<20 per cent) and high (>20 per cent) and according this classification the characters plant height, leaf size/leaf area, internodal length, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility, and pollen size showed high genetic advance while it is low for all other characters.

Renu (2000) reported that high heritability coupled with high genetic advance values for plant height, spathe size, position of candle, number of flowers per candle and days to initiation of female phase. Mayadevi (2001) inferred that plant height, leaf area, spadix length, inclination of candle with spathe and spathe size showed high heritability and genetic advance. Asish (2002) recorded high heritability and genetic advance values for plant height, internode length, leaf area, candle length, inclination of candle to spathe, number of flowers per candle, life of spadix, days to initiation of female phase, days to inter phase, durtaion of male phase, pollen fertility and anthocyanin content.

Premna (2003) recorded high heritability and genetic advance for leaf area, anthocyanin content, inclination of candle, life of spadix, and pollen fertility. Pravin (2004) reported high heritability and genetic advance values for characters plant height, internode length, leaf size, candle length, inclination of candle with spathe, life of spadix, days to initiation of female phase, duration of male phase, pollen fertility and pollen size. Shiva and Nair (2008c) reported high heritability and genetic advance for leaf area, shelf life of flower on plant and plant height. Comparison between heritability and genetic advance was shown in Fig. 3.

5.4 CORRELATION STUDIES

Correlation provides information on the nature and extent of association between characters in a population. The component character always show



X_1 Plant height (cm)

X_2 Leaf size/leaf area (cm^2)

X_3 Internodal length (cm)

X_4 Number of leaves per plant

X_5 Days from emergence to maturity of leaves

X_6 Days from emergence to maturity of inflorescence

X_7 Spathe size (cm^2)

X_8 Total Anthocyanin content (mg/g)

X_9 Spadix length (cm)

X_{10} Inclination of candle with the spathe (degrees)

X_{11} Number of flowers/Spadix

X_{12} Life of spadix (days)

X_{13} Days to initiation of female phase

X_{14} Duration of interphase

X_{15} Duration of male phase

X_{16} Pollen fertility (per cent)

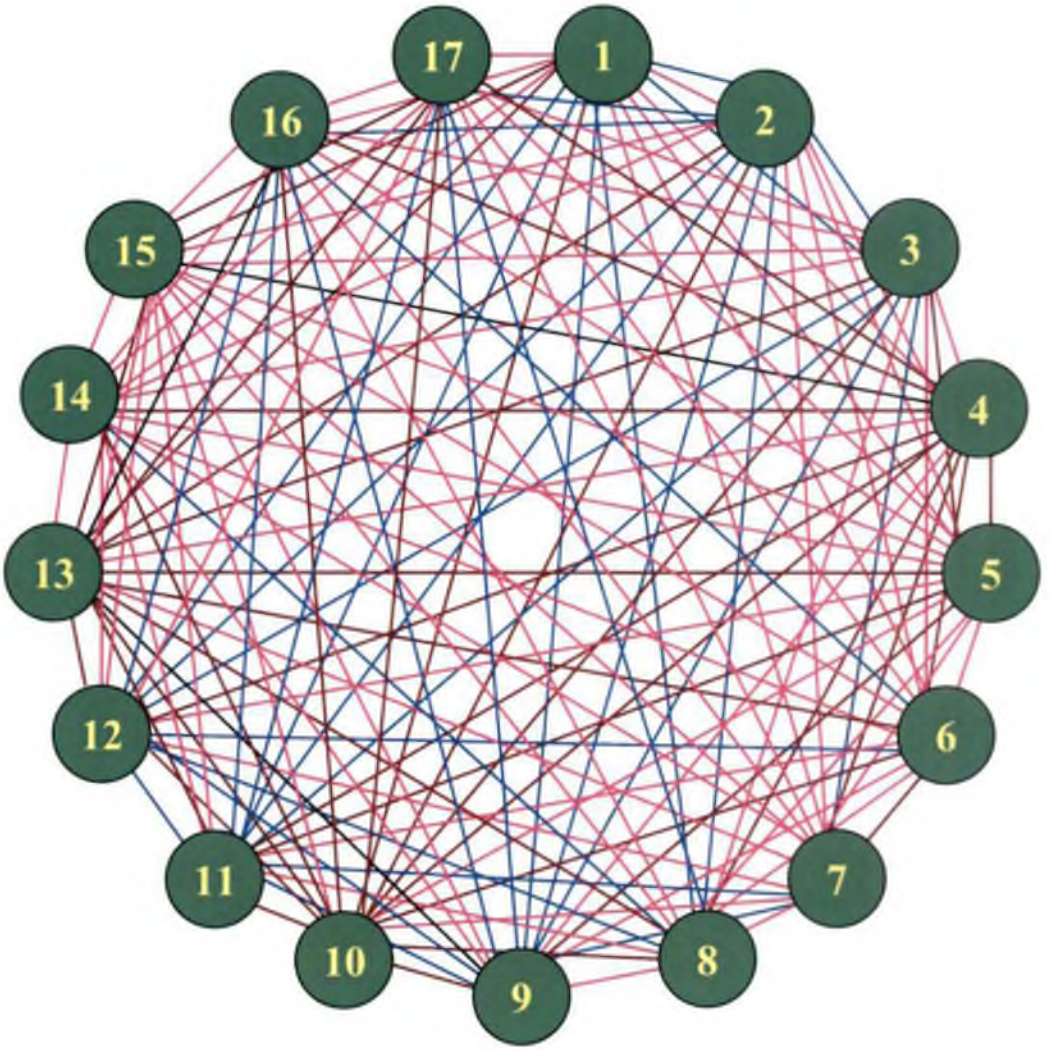
X_{17} Pollen size (μ)

Fig. 3 Heritability and genetic advance of seventeen characters in *Anthurium andreanum*

interrelationship. When the breeder applies selection on a trait the population under selection is not only improved for that trait but also improve in respect of other characters associated with it. This facilitates simultaneous improvement of two or more characters. Genetically related characters tend to move in the same direction under selection favouring any one of such related traits. Such correlated response to selection is the basic property of quantitative traits under the control of polygenic system. The quantitative traits governed by one or a few genes do not exhibit correlated changes on selection (Sharma, 1994). The genotypic correlation (inherent) between the characters helps to differentiate the vital association useful in breeding from non-vital ones, Falconer (1989).

The significance of pair-wise correlation are presented in Fig. 4, 5 and 6. The genotypic, phenotypic and environmental correlations between all the possible pairs of characters are discussed. In the present study plant height showed highly significant positive phenotypic correlation with leaf size/leaf area, internodal length, total anthocyanin content, spadix length, number of flowers per spadix and life of spadix. If a positive correlation is observed for a pair of characters, certainly improvement in one character will improve the other character also, thus helping a breeder to select characters on the correlated response to selection. If the improvement in one character results in a decrease in other character, this will also help the breeder in the selection of character if necessary. Similar results have been reported by Maya Devi (2001), Asish (2002), Premna (2003) and Pravin (2004).

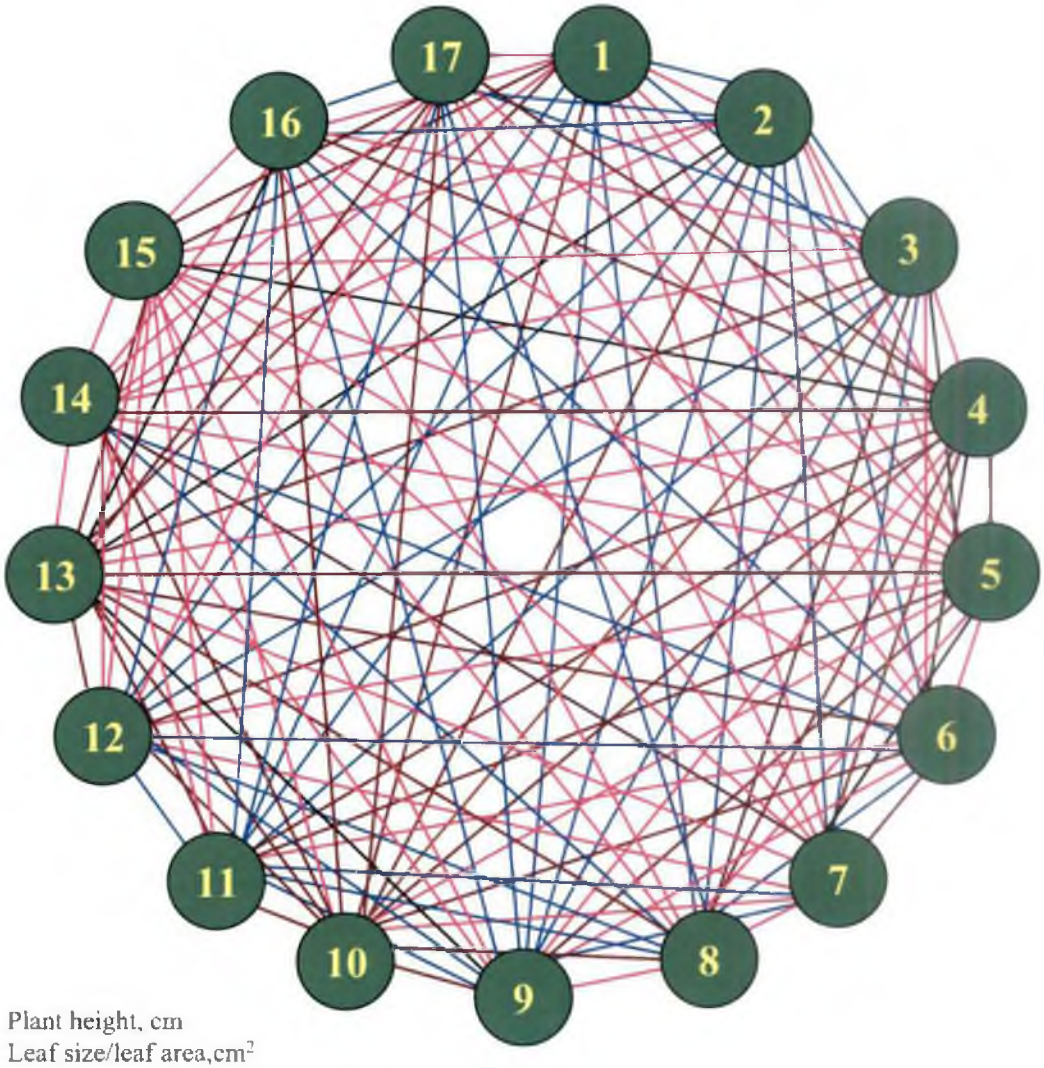
Plant height showed positive genotypic correlation with all the characters except days from emergence to maturity of leaf, inclination of candle with spathe, days to initiation of female phase and duration of male phase. Life of spadix which is an important commercial character was found to be positively correlated with plant height, leaf size/leaf area, internodal length, days from emergence to maturity of inflorescence, total anthocyanin content, Spadix length, number of flowers per spadix and pollen fertility. Asish (2002) observed positive correlation of life of spadix with leaf area and candle length. Premna (2003) reported positive



1 Plant height, cm
2 Leaf size/leaf area,cm^2
3 Internode length, cm
4 Number of leaves per plant
5 Days from emergence to maturity of leaves, days
6 Days from emergence to maturity of inflorescence, days
7 Spathe size (cm^2)
8 Total anthocyanin content
9 Spadix length, cm
10 Inclination of candle with the spathe,degrees
11 Number of flowers/spadix
12 Life of spadix, days
13 Days to initiation of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive significant
Positive
Negative
Negative significant

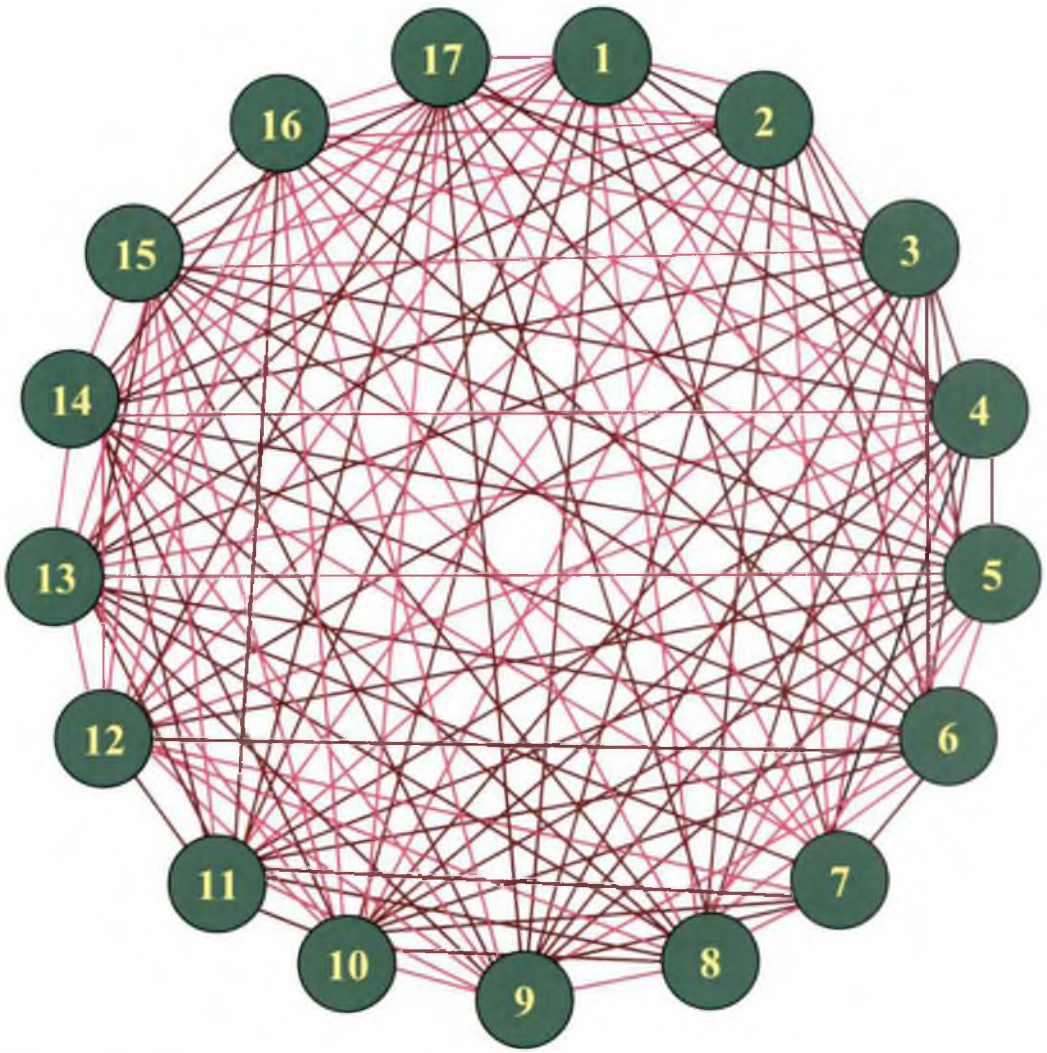
Fig. 4 Phenotypic correlation coefficient among the characters



1 Plant height, cm
2 Leaf size/leaf area,cm^2
3 Internode length, cm
4 Number of leaves per plant
5 Days from emergence to maturity of leaves, days
6 Days from emergence to maturity of inflorescence, days
7 Spathe size (cm^2)
8 Total anthocyanin content
9 Spadix length, cm
10 Inclination of candle with the spathe,degrees
11 Number of flowers/spadix
12 Life of spadix, days
13 Days to initiation of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive significant
Positive
Negative
Negative significant

Fig. 5 Genotypic correlation coefficient among the characters



1 Plant height, cm
2 Leaf size/leaf area,cm^2
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6 Days from emergence to maturity of inflorescence, days
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8 Total anthocyanin content
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10 Inclination of candle with the spathe,degrees
11 Number of flowers/spadix
12 Life of spadix, days
13 Days to initiation of female phase, days
14 Duration of interphase, days
15 Duration of male phase, days
16 Pollen fertility, per cent
17 Pollen size,μ

Positive
Negative
Negative significant

Fig. 6 Environmental correlation coefficient among the characters

correlation of life of spadix with internodal length, leaf area, days from emergence to maturity of inflorescence, candle length and pollen fertility.

In the present study number of flowers per spadix was found to have significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, spadix length, total Anthocyanin content, life of spadix, pollen fertility and pollen size. Similar results have been reported by Renu (2000), Binodh et al. (2004), Shiva and Nair (2008a) and Shiva and Nair (2008c). In the present study spadix length showed significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, number of flowers per spadix, life of spadix and pollen size while it showed significant negative correlation with days to initiation of female phase. Similar results have been reported by Maya Devi (2001), Asish (2002) and Pravin (2004) supports the findings in this investigation. Environmental correlations are absent for almost all pairs of characters except between number of leaves/spadices per plant and spathe size indicating the influence of environment on this character.

5.5 PATH ANALYSIS

The path analysis reveals whether the association of the component characters with yield is due to their direct effect on yield or is a consequence of their indirect effect via some other trait(s). Thus path coefficient analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effects of the component characters on the yield, on the basis of which improvement programme can be devised effectively. If the correlation between yield and any of its components is due to the direct effect, it reflects a true relationship between them and selection can be practiced for such a character in order to improve yield. But if correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select the latter trait through which the indirect effect is exerted.

In the present investigation, the highest positive and direct effect on number of flowers per spadix was exhibited by spadix length followed by plant

height, leaf size/ leaf area, life of spadix, days to initiation of female phase, pollen size and pollen fertility while spathe size, anthocyanin content, internodal length, days to inter phase and days from emergence to maturity of inflorescence had negative direct effects. In the present study, leaf size showed a positive direct effect on number of flowers per candle in accordance with earlier findings of Binodh et al. (2004).

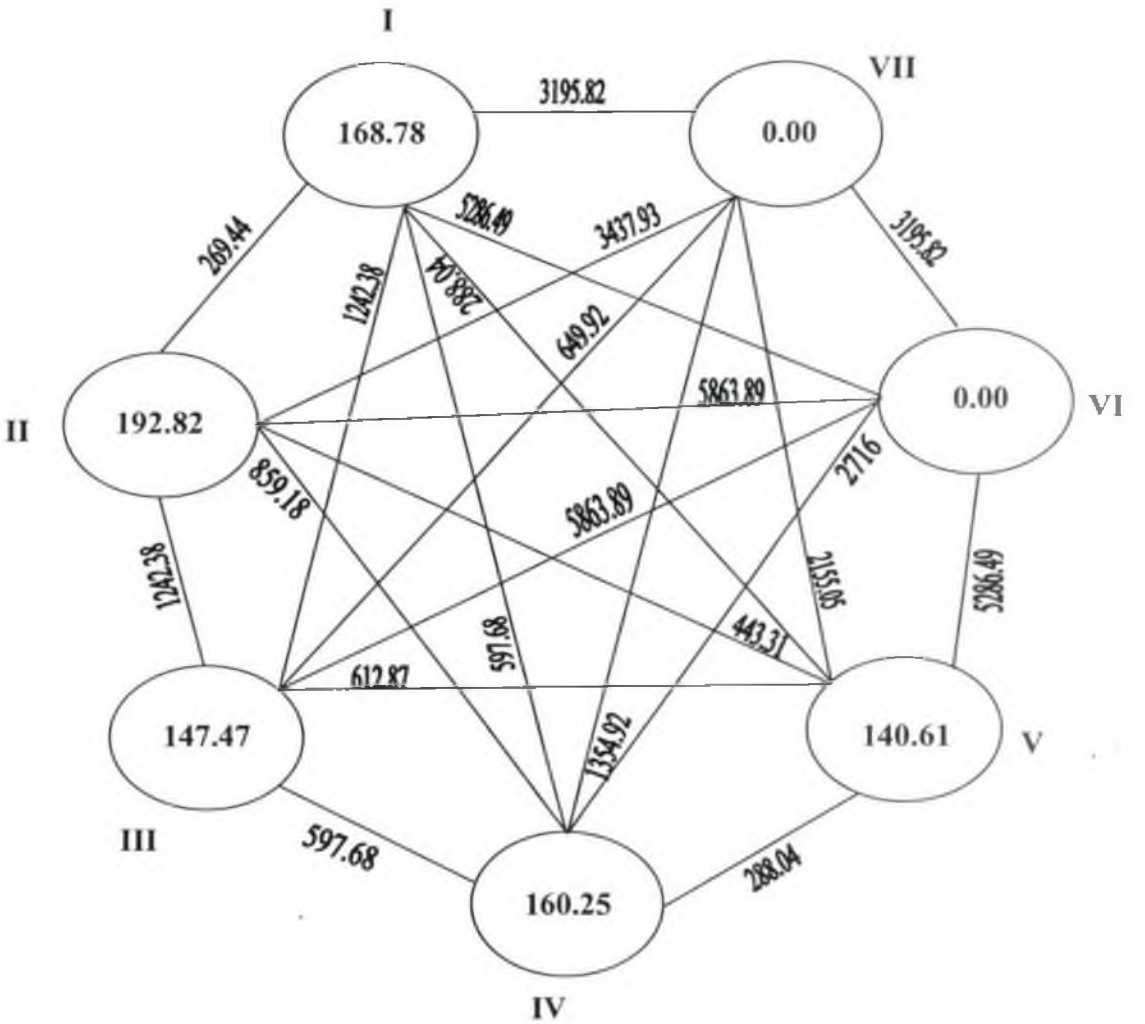
From the present study it is evident that spadix length, plant height and leaf size/ leaf area are more associated with dependent variable *i.e.*, number of flowers per spadix. About 27 per cent of the variation in flower production was attributed by the environment. The residue obtained was low indicating that the component characters taken for path analysis well explained the cause and effect system.

5.6 GENETIC DIVERGENCE

The importance of genetic diversity of parents in hybridization programme has been emphasised by many workers. The more diverse the parents with in a reasonable range, higher would be the chances of improving the characters in question. Mahalanobis D^2 statistic has been found to be a powerful tool in the hands of plant breeders to assess the degree of relationship among the genotypes and to group them based on their phenotypic expression.

Following Mahalanobis D^2 statistic (Mahalanobis, 1936), the 40 genotypes were grouped into seven clusters. The maximum number of genotypes (17) were included in Cluster I, followed by cluster II (7), cluster III (5), cluster IV (5) and cluster V (4). Clusters VI and VII had one genotype each.

The inter and intra cluster distances are presented in Fig. 7. Maximum divergence was shown between the Clusters II and VI, while the minimum divergence between clusters I and II. The intracluster distance was highest for the Cluster II. Among the 13 characters considered life of spadix contributed maximum towards divergence followed by days to initiation of female phase.



The values in circles indicate intracluster D values and others indicate intercluster D values

Fig. 7 Cluster diagram

Grouping of genotypes into different clusters did not reflect the geographical origins of the varieties. Comparison among clusters for mean value of various characters are presented in Fig. 8 and character contribution towards divergence presented in Fig. 9.

Maya Devi (2001) grouped 100 genotypes of anthurium into seventeen clusters based on genetic divergence using Mahalanobis D^2 statistics. The cluster 3 had the highest number of genotypes (15) followed by cluster 2 (13). D^2 analysis has also been effectively employed for identification of traits contributing to genetic divergence and grouping of cultivars in vegetatively propagated crops like banana (Valsalakumari et al., 1985; Mercy and George, 1987, 1988) and sugarcane (Punia et al., 1983; Santhi, 1989).

5.7 SELECTION INDEX

Selection of genotypes based on a suitable index is highly efficient in any breeding programme. An estimation of discriminant function based on reliable and effective characters is a valuable tool for the practical plant breeder. Superior genotypes can be selected from a collection of germplasm using a selection index employing the discriminant function.

In the present study selection index for the genotypes was computed on the basis of 13 characters namely plant height, leaf size/leaf area, internodal length, days from emergence to maturity of inflorescence, spathe size, total anthocyanin content, Spadix length, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, pollen fertility and pollen size.

The maximum selection index value obtained for Liver Red followed by PR x LR and PR x DT (1) and minimum for Rembolina. The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the D^2 analysis. The selection values of various genotypes arranged in descending order were showed in Fig.10. The genotype in Cluster VII (Liver Red) topped first followed by the genotype in Cluster VI (PR x LR), while

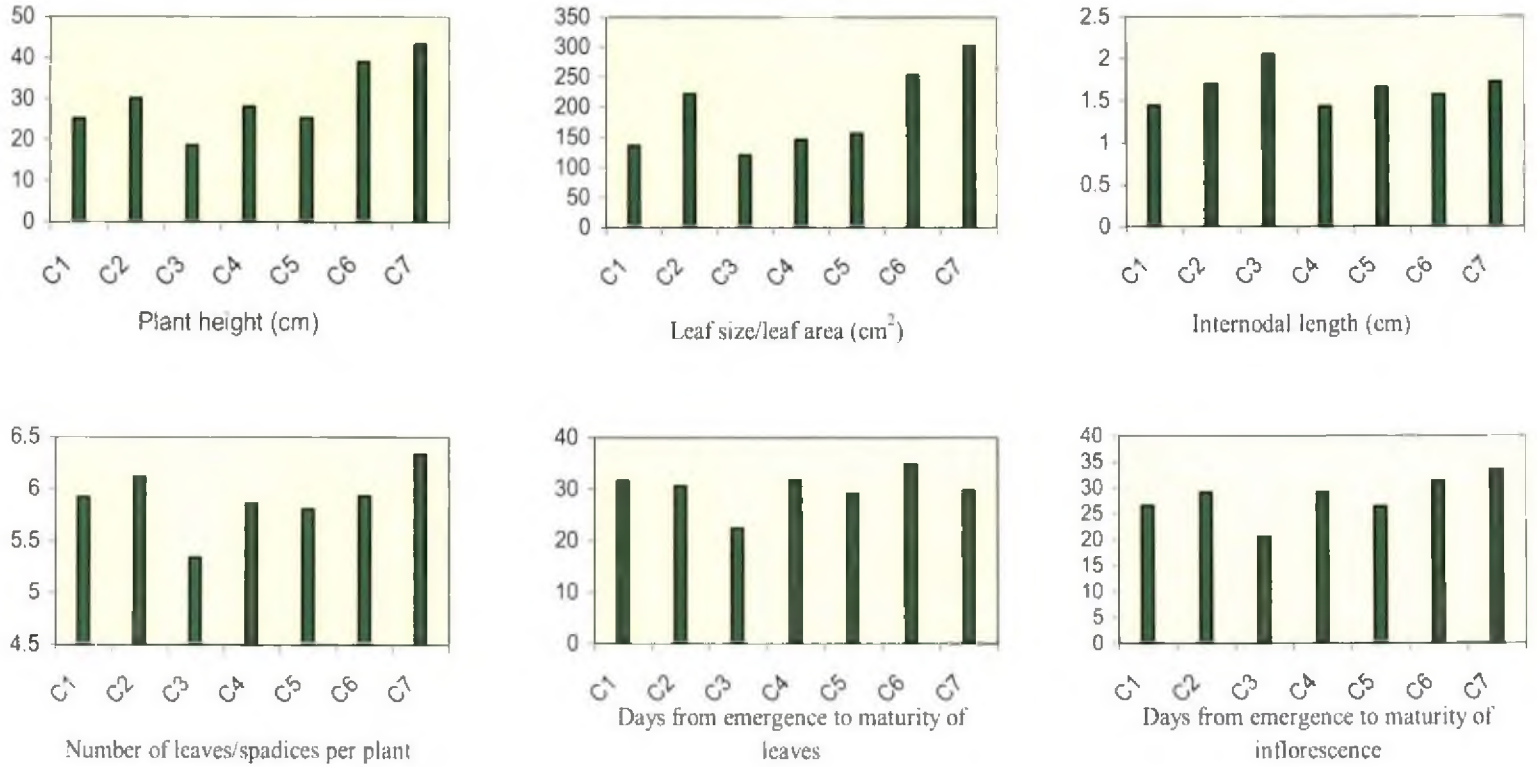


Fig. 8 Characterwise performance of genotypes within clusters

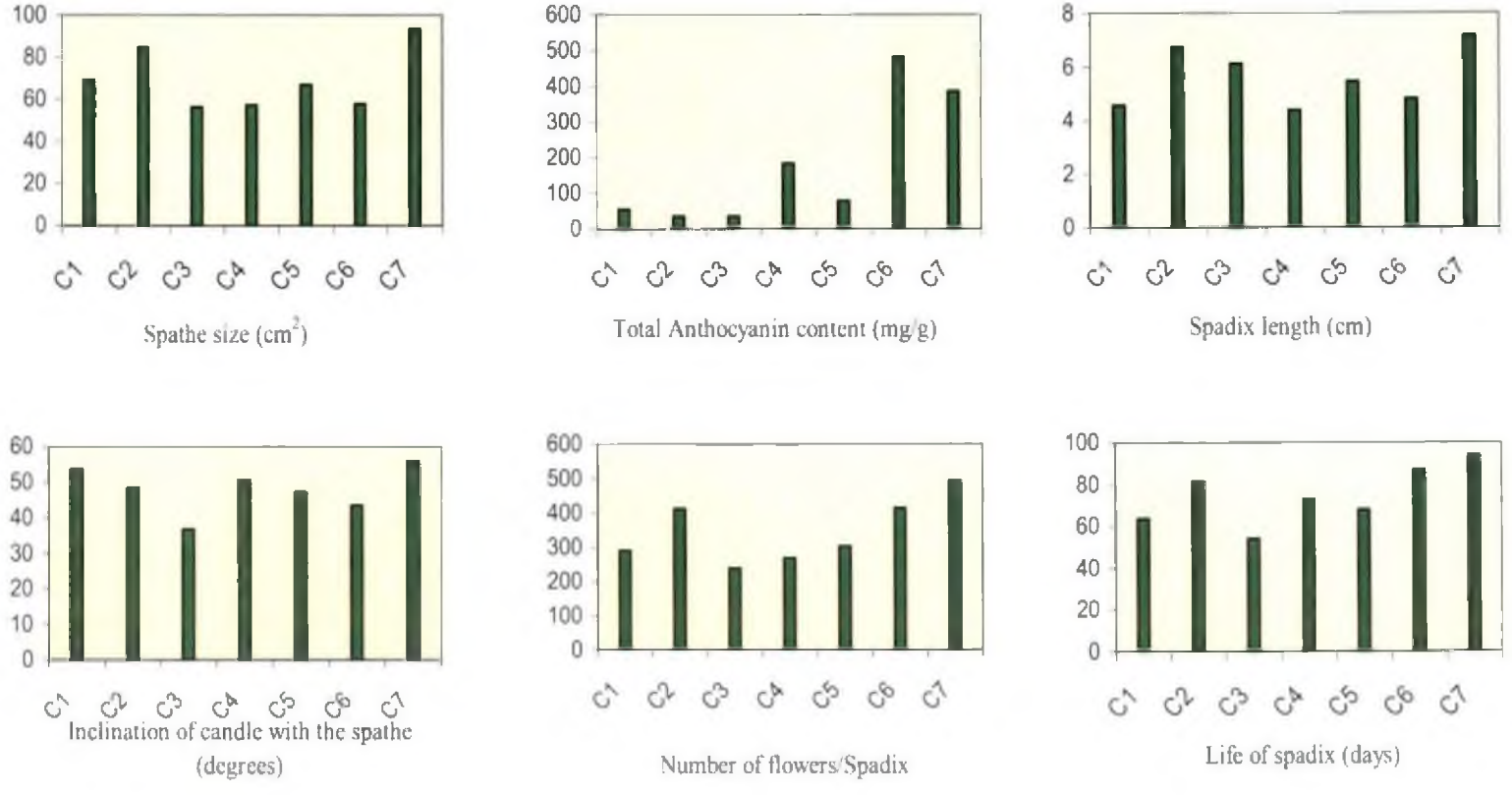


Fig. 8 (Cont.) Characterwise performance of genotypes within clusters

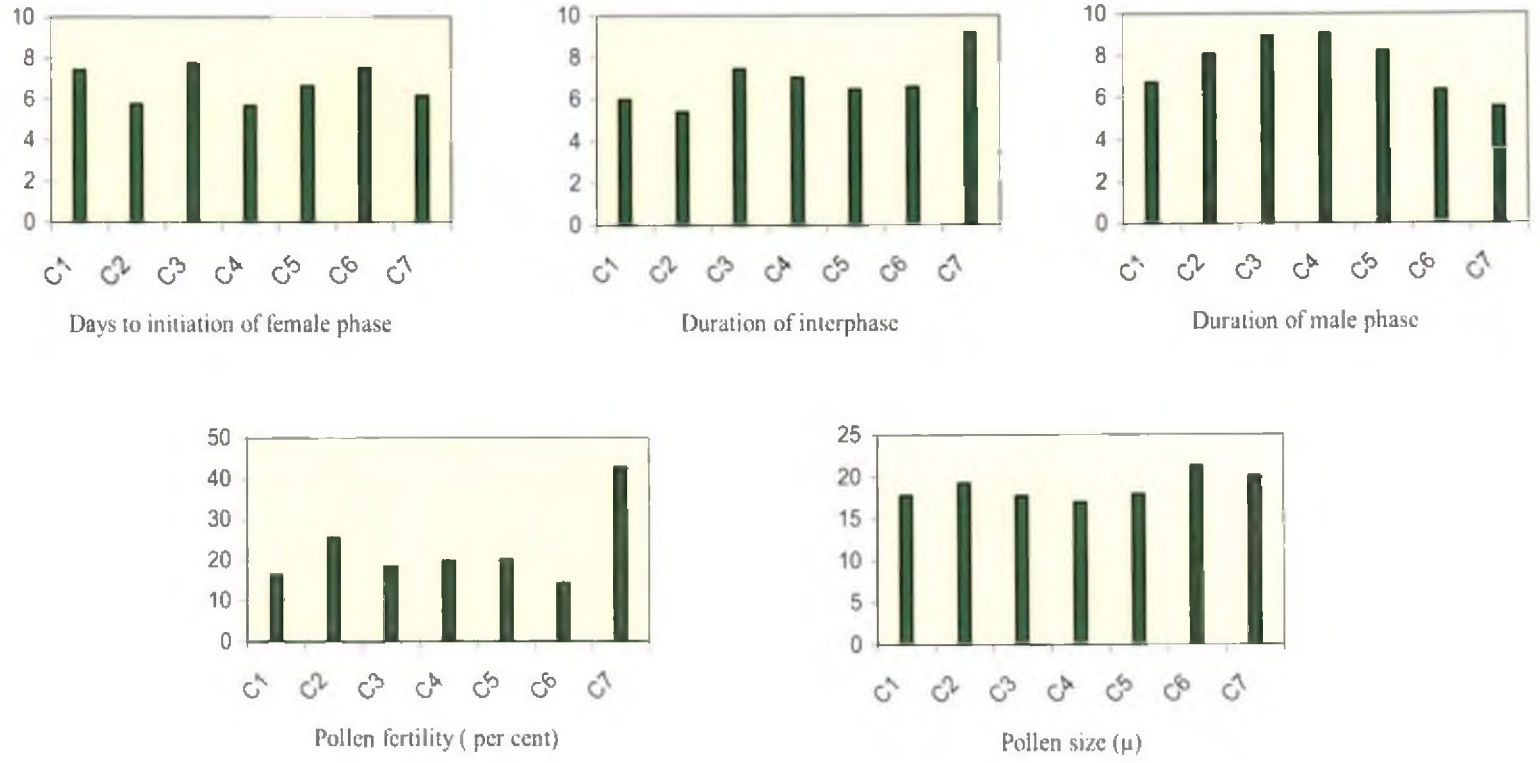


Fig. 8 (Cont.) Characterwise performance of genotypes within clusters

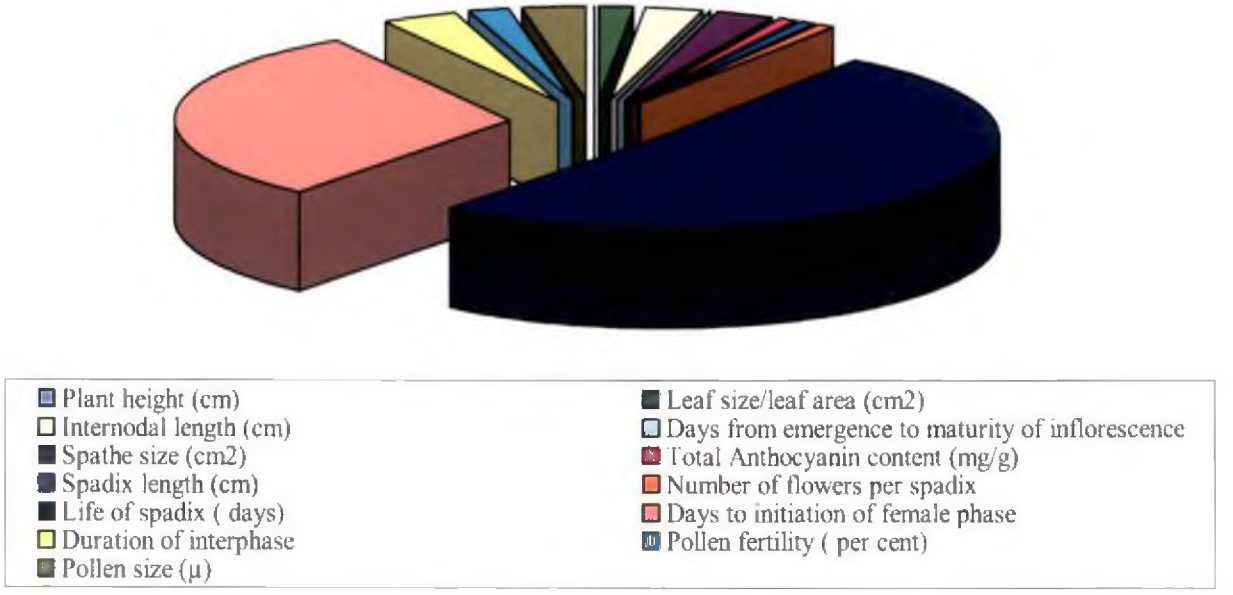


Fig. 9 Character contribution towards divergence

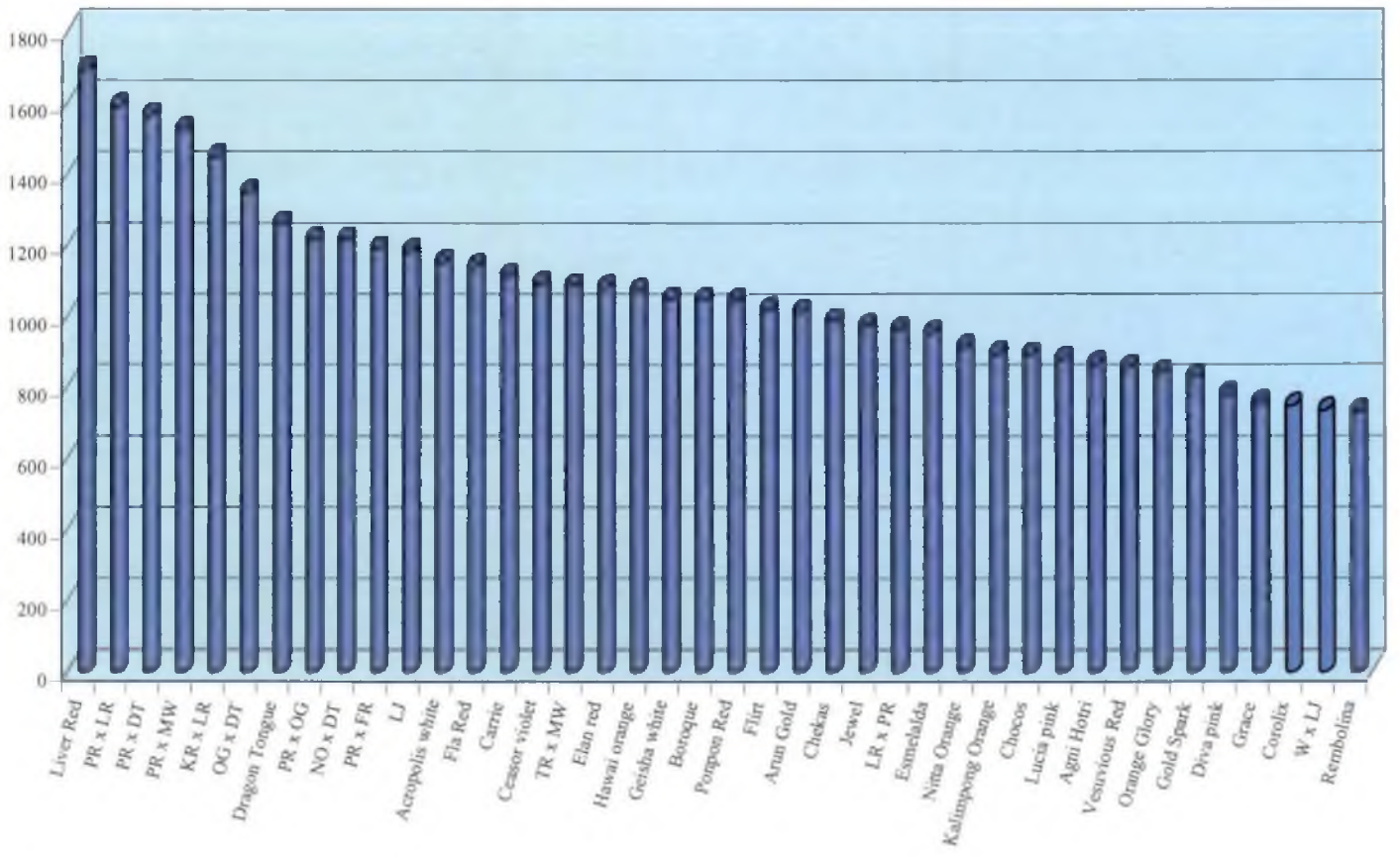


Fig. 10 Selection index values of genotypes in descending order

the genotypes in Cluster I (Lucia pink, Agnihotri, Vezuvious Red, Gold Spark, Diva pink, Grace, Corolix, W x LJ and Rembolina,) with the least index values.

Binodh and Devi (2005) worked out the selection indices for 50 anthurium (*Anthurium andreanum*) genotypes on the basis of 17 characters. Based on the analysis the highest selection index values were observed in genotype LR x DT followed by FR x MW. Shiva and Nair (2008a) reported that selection index comprising the characters like spathe size and shelf-life of flower on plant on flower yield can be considered highly dependable and reliable characters for selection to improve yield in anthurium.

5.8 COMPATIBILITY STUDIES

Anthurium is a highly cross-pollinated crop. Hybridization followed by selection is the most common method for improving anthurium. Although hybridization appears to be successful at the beginning in many crosses, combination may still be incompatible. This is evidenced by yellowing of the candle two to three months after fertilization. So cross-compatibility analysis is done before undertaking genetic improvement programmes.

Hybridization and selection was pointed out by Kamemoto and Nakasone (1955), as the accepted method for improving anthuriums. Both intraspecific as well as interspecific hybridization was used by early anthurium breeders. Birdsey (1956) attributed much of the variation in blistering patterns of spathes of *A. andreanum* to interspecific hybridization. Interspecific cross compatibility, evaluation among 56 species of *Anthurium* by Sheffer and Kamemoto (1976) revealed that hybrids of *A. andreanum* and *A. scherzerianum* were not readily obtainable. But they got hybrids of *A. andreanum* with six other closely related species. Kaneko and Kamemoto (1978) suggested that cultivated anthurium forms were derived from interspecific hybrids which are supposed to have arisen spontaneously in early species collections. A new interspecific hybrid, Southern Blush, was produced by Henny *et al.* (1988) by crossing a large pink-flowered *A. andreanum* cv. with *A. amnicola.* Kuehnle *et al.* (1994) transferred systemic

resistance to bacterial pathogens from *A. antioquiense* to cultivated *A. andreanum* and got resistant hybrids.

Hybridization between selected varieties with good cross compatibility was recommended by Mercy and Dale (1994). In 1997 Anthura submitted for registration a variety Champion, derived from *A. andreanum* hybrids. Henny (1999) described a new *Anthurium* hybrid Red Hot which originated from hybridization of *A. amnicola.* Dressler with an unnamed selection of *A. andreanum* (accession code G-79) one of the resulting F_1 hybrids was designated as the female parent and crossed with *Anthurium* into Lady Jane to produce the progeny, from which Red Hot a miniature type was selected.

The three important parameters used for compatibility analysis in the present study were percentage of fruiting candles, percentage of fruit set per candle and percentage of seed germination. In the present study a total of 127 crossings were attempted of which 80 were successful. Among the cross combinations attempted the percentage of fruiting candles was 100 per cent for 41 crosses and 50 per cent for 39 crosses. No fruit bearing candles were produced in 47 cross combination attempted. Among the 15 genotypes, percentage of fruiting candles was maximum for PR x OG (90.00 per cent) followed by AW (66.67 per cent) and PR x LR (65.00 per cent). The lowest value 5 per cent was obtained for Esmeralda and 11.11 per cent for Dragon's Tongue. Hybridization work by Sheffer and Kamemoto (1976) revealed that 81 per cent fruiting spadices was obtained through self polinations, 65.4 per cent intraspecific crosses and 28 per cent through interspecific crosses. Sindhu (1995) observed that in the six anthurium varieties White had the maximum percentage of fruiting candles (93 per cent) and the lowest for Kalympong Red. Renu (2000) reported that selfing and crossing gave 22.50 pr cent and 31.06 per cent success respectively in the ten selected *A. andreanum* varieties studied by her. Among the 10 female parents Premna (2003) observed a 100 percentage of fruiting candle for W x LJ. Among the 12 successful crosses percentage of candles bearing fruits was 100 per cent for six crosses (Pravin, 2004).

In anthurium the fruit is a berry Mercy and Dale (1994) observed that a candle with developing fruits could be visually identified from the second month of fertilization, as it becomes swollen and fleshy with developing fruits embedded on it. The colour of ripe berries varied from creamish yellow to dark red. Among the individual cross combinations in the present study, (PR x OG) x (OG x DT) recorded the highest number of fruits per candle (85) followed by LR x DT (83). The crosses (OG x DT) x (PR x OG), LR x FR and (PR x OG) x DT also recorded higher number of fruits per candle. Esmeralda x (PR x OG) and (KR x LR) x LJ recorded lowest number of fruits per candle. A well-fertilized candle may have up to 100 to 200 fruits per candle according to Mercy and Dale (1994). In the cross compatibility study conducted by Sindhu (1995), the cross Pink x Honeymoon Red had 170 fruits per candle while the self Kalympong Red x Kalympong Red had only two fruits per candle. Renu (2000) obtained PR x LR and PR x CR as the crosses with highest number of seeds (183 and 162). Premna (2003) obtained the highest number of fruits for the cross (OO x KR) x C (120) followed by (OO x KR) x H (103). Among the 12 successful crosses studied by Pravin (2004), maximum number of 113 fruits was obtained for the cross ('LR x PR') x OG followed by ['FR x MW (1)'] x LR with 88 fruits. The average number of fruits per candles was highest for 'LR x PR' and lowest for 'PR x FR (1)'.

Absence of full fruit set in spadix was identified as a major problem in the development of *Anthurium* cultivars by Zimmer (1986). In the present study also the percentage of fruit set was below 50 per cent for all the successful crosses. The cross (PR x OG) x (OG x DT) recorded the highest fruit set (21.14 per cent) followed by LR x DT (16.76 per cent). The lowest was for the cross Esmeralda x (PR x OG) (1.75 per cent). The average percentage of fruit set was highest for the genotype Liver Red (14.47 per cent) with three crosses and lowest for Ceasor violet (1.34 per cent) with five crosses. In the study using six anthurium varieties, conducted by Sindhu (1995) the cross P x HR (44.30 per cent) and lowest for the cross KR x KR (0.40 per cent). Renu (2000) observed the highest value for fruit set for the cross PR x LR (57.60 per cent). Premna (2003) observed highest fruit

set for the cross (OO x KR) x C (34.29 per cent). Pravin (2004) reported that the percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for 'PR x FR (1)' and 'LR x PR' respectively.

In the present study most of the varieties took more than five months duration from the day of pollination to the day of fruit maturity and it ranged from 4.5 to 7 months. Similar duration of fruit maturity was observed by Sindhu (1995). She has recorded that this duration ranged from 5 to 6.8 months. Duration of fruit maturity in *Anthurium* was recorded as 6 –8 months by Singh (1987), as 5 to 12 months by Zimmer (1986) and as 4 to 7.5 months by Mercy and Dale (1994). Among the 10 varieties studied by Renu (2000), the duration ranged from 4.4 months in Lady Jane Red to 6.1 months in Ceylon Red. Premna (2003) recorded that duration from the day of pollination to the day of fruit maturity ranged from 3.5 to 5.5 months. Pravin (2004) observed that the duration of fruit maturity ranged from 4 to 8 months. All the reports together with the observations of the present study confirm that the long fruit ripening period in *A. andreanum* is one of the reasons that contribute to the slow progress of *Anthurium* breeding programmes.

According to Zimmer *et al.* (1986) the berries contained two to three seeds. Mercy and Dale (1994) had reported that *Anthurium* berries contained one or two seeds. In the present study it was found that all the crosses showed higher percentage of berries bearing single seeds except the cross FR x LR. In the compatibility study by Sindhu (1995) also the percentage of single seeded berries were more than double seeded berries. Percentage of single seeded berries ranged from 37.21 to 100 per cent. In a berry with two seeds one of the seeds was usually smaller than another. In a berry largest seed among the two seeded berries were observed for the crosses AW x (PR x OG) (3.53 x 2.27 mm) followed by [(PR x LR) x (PR x DT (2)] (3.53 x 2.25 mm). Sindhu (1995) also observed that when two seeds were seen in a berry usually one was smaller. Renu (2000) obtained largest seeds in double seeded berries for the crosses PR x LR, PR x DT

and MW x LR and among the single seeded crosses, Tropical Red x Merengue White had the largest size. Among single seeded berries maximum seed size was for AW x (PR x OG)(4.17 x 3.45 mm). Premna (2003) reported that in the cross (PR x LR) x T only single seeded berries were present and it had maximum value. Pravin (2004) reported that most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross between 'LR x PR' and 'Orange Glory'.

In some ripe berries it was observed in the present study, that the seeds at the time of harvest had the tip of radicle emerging from the seed coat, such seeds germinated immediately. The number of days taken for germination ranged 4 to 9 days. Anthurium seeds, according to Singh (1987) took six to eight days for germination. Criley (1989) reported that seeds germinated within 14 days. In the six varieties studied by Sindhu (1995) the number of days for germination ranged from 6 to 14 days while it was 3 to 12 days in a study by Renu (2000). Premna (2003) and Pravin (2004) observed the number of days for germination ranged from four to nine days.

Highest percentage of germination was obtained for the cross (PR x LR) x C (71.67 per cent) followed by (PR x OG) x LR (70.83 per cent) and lowest by [PR x DT (2)] x LJ (19.05 per cent). The three crosses, DT x LR, (KR x LR) x LJ and Esmeralda x (PR x OG) did not germinate at all. In the study by Renu (2000), highest germination percentage was for the cross DT x MW and lowest for MG x LR (6.9 per cent). In her study, the crosses DT x LR, MG x CR and MG x MW did not germinate.

Survival of seedlings at four to six months in the present study showed that 57 out of 73 crosses were carried beyond four months. The seedlings of the 16 crosses failed to survive. No cross showed 100 per cent survival. The highest rate was shown by the cross (KR x LR) x DT (81.25 per cent) followed by (KR x LR) x (PR x OG), [PR x DT (2)] x (PR x OG) and [PR x DT (2)] x (PR x LR) (80.00 per cent) and lowest by LJ x (PR x OG) (37.50 per cent). The highest

survival percentage was showed by the female parent Liver Red (69.93 per cent). So in addition to low levels of fruit set and seed germination the high mortality of seeds in the early stages can be considered as a major constraint in the development of anthurium hybrids. Renu (2000), out of 34 cross combinations that germinated only 31 cross combinations survived for more than four months. Premna (2003) found that highest survival percentage was for the cross (FR x KR) x A (75.26 per cent) and lowest by (KR x LR) x A (32.25 per cent). In the study by Pravin (2004) reported that seedlings of 9 out of 12 crosses that germinated survived for more than four months. The highest average survival was recorded by 'OG x DT' (with only one cross) and lowest was recorded for the genotype 'PR x MO'.

Compatibility parameters estimated based on the performance of the fifteen genotypes as pollen parents. Highest percentage of candles bearing fruits was shown by PR x OG (76.92 per cent) followed by Fla Red (66.67 per cent), Dragon's Tongue (65.38 per cent) and PR x LR (61.11 per cent). Lowest percentage were recorded for Flirt and KR x LR (21.43 per cent). Number of fruits per candle was the highest for the genotype [PR x DT (2)] (39.75) followed by PR x OG (39.42), Dragon's Tongue (39.18) and Acropolis white (37.71). In LJ, Flirt and KR x LR the number of fruits were relatively lower (14.25, 16.5 and 18 respectively). Higher percentage fruit set was observed for the genotypes Dragon's Tongue (9.90 per cent) while it was lowest in Lady Jane (2.77 per cent). Percentage of seed germination was the highest for Fla Red (45.03 per cent). Renu (2000) in her study, estimated compatibility parameters based on the performance of the ten varieties as pollen parents.

A novel method for easy computation and understanding of compatibility reactions was devised by Renu (2000). A similar type of classification is done in the present study also. Accordingly, the percentage of fruiting candles which ranged from 0 to 100 per cent were divided into four compatibility classes. The percentage of fruit set in the present study ranged from 1.75 per cent to 21.14 per cent and these values were classified into four classes. The percentage of seed

germination, which ranged from 19.05 to 71.67 per cent. The crosses of the fifteen genotypes as female were linearly scored on the basis of percentage of fruiting candles, fruit set and seed germination. It was found that the female parents PR x OG, PR x LR, Lady Jane, OG x DT and PR x DT (2) got the high varietal scores. Similarly fifteen genotypes as male were linearly scored, among male parents PR x OG, DT, OG x DT, FR and PR x LR got the high varietal scores. So PR x OG, OG x DT and PR x LR could be judged as the best male as well as female parents. The highest score for an individual cross was obtained for the crosses (PR x OG) x (OG x DT), (PR x LR) x C, FR x DT, AW x (PR x OG), (OG x DT) x (PR x OG), (PR x LR) x (PR x OG),PR x DT (2) x (PR x OG), (OG x DT) x LR, LJ x LR, (PR x OG) x DT, (PR x OG) x LR, (PR x OG) x (PR x LR) and (PR x LR) x FR. So these were the most compatible crosses. The female parents Esmeralda, Dragon's tongue, and Ceasor Violet showed poor performance. Among the male parents KR x LR and Flirt showed poor performance during the course of study while Esmeralda and Ceasor Violet not produced pollen during the crossing period.

Seedlings of the successful crosses were evaluated for morphological characters. Among the crosses the maximum number of days was taken by the cross LJ x (PR x LR) (36.33) followed by [(KR x LR) x (PR x LR)] (35.60) and the least number of days for maturity of leaves was taken by C x (PR x OG) (23.80). Number of leaves was ranged from 4.50 in DT x FR to 6.33 in [(PR x OG) x (OG x DT)]. The leaf area was maximum for the cross LR x FR (21.05 cm^2) and it was minimum for LJ x (PR x OG) (15.16 cm^2). Variation in the leaf area reported earlier by Mayadevi (2001), Asish (2002), Premna (2003) and Pravin (2004). Shiva and Nair (2008 b) reported that the mean leaf area ranging from 5.33 to 16.43 cm^2. The colour of young leaf showed a range from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green. Mercy and Dale (1994), Sindhu (1995), Premna (2003) and Pravin (2004) revealed the same results.

Summary

6. SUMMARY

The present study "Cross compatibility analysis for production of hybrids in *Anthurium andreanum* Linden" aimed at to identify suitable parents with commercial qualities and to determine the cross compatibility among the selected parents. The present investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2006-2009. The study was conducted in two experiments. Experiment-I for Evaluation of genotypes to identify suitable parents for hybridization and Experiment-II for Compatibility studies. The study revealed tremendous scope for genetic improvement in this crop. The results of the analysis were summarised below.

- In experiment-I, 29 varieties and 11 different hybrid genotypes of anthurium showing variations in spathe colour, shape and size and other commercially valuable morphological characters, generated through hybridization in an NARP (SR) Project available in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani and from approved commercial growers were utilised for the study. The selected plants were raised in the pot culture experiment under completely randomised design with three replications. Observations were recorded on various morhological and floral characters to identify fifteen parent varieties for hybridization.

- Analysis of variance revealed significant variation among the eighteen quantitative characters studied viz., plant height, leaf size/leaf area, internodal length, number of suckers per plant, number of leaves/spadices per plant, days from emergence to maturity of leaves, days from emergence to maturity of inflorescence, spathe size, total anthocyanin content, spadix length, inclination of candle with the spathe , number of flowers /spadix , life of spadix , days to initiation of female phase, days to interphase, duration of male phase, pollen fertility and pollen size.

- The plant height ranged from 17.33 cm in Nitta Orange to 43.25 cm in Liver Red. The leaf area was minimum for Rembolina and maximum for PR x DT. Internodal length ranged from 0.97 cm in Agnihotri to 2.02 cm in Esmeralda. Sucker production was highest for Liver Red. Rembolina had maximum number of leaves/spadices per plant. The least number of days for maturity of leaves was observed by PR x OG. Grace recorded the lowest mean value for days from emergence to maturity of inflorescence.

- The maximum spathe size was observed for Acropolis White and minimum for W x LJ. The total anthocyanin content showed wide variation among the genotypes and it ranged from 9.73 mg/g to 482.05 mg/g. Spadix length was maximum for OG x DT while the minimum was for LR x PR. Orange Glory had lowest angle between the candle and the spathe. The maximum number of flowers /spadix was observed for the genotype KR x LR and minimum for LR x PR and Corolix. PR x DT (1) recorded the highest mean value for the life of the spadix. The mean number of days to initiation of female phase ranged from 3.55 to 10.55. The highest mean number of days to interphase was shown by Nitta Orange. The mean duration of male phase ranged from 3.37 to 10.89.

- Pollen fertility estimated using acetocarmine method indicated that most of the genotypes had low fertility values. Liver Red had the highest pollen fertility of 43.01 per cent followed by Lady Jane (36.14 per cent). Pollen emergence was low in the months from March to June, during which the average maximum and minimum temperatures were relatively high. Pollen emergence was highest during October to December months. The mean size of the pollen ranged from 14.67μ in Arun Gold to 25.18 μ in Lady Jane. Pollen shape ranged from round to oval and majority of the genotypes had round pollen.

- Variability studies revealed that high PCV (Phenotypic coefficient of variation) along with high GCV (Genotypic coefficient of variation) were present for anthocyanin content, pollen fertility, leaf size/leaf area, spathe

size and spadix length. This suggests that there is an excellent scope for improvement of these characters through selection. Lower values of GCV and PCV were estimated for the characters days from emergence to maturity of leaves, days from emergence to maturity of inflorescence and number of spadices per plant indicating low variability and thus limiting the scope for further improvement through selection. The characters, total anthocyanin content, pollen size, life of spadix and pollen fertility showed low difference between PCV and GCV revealing that the environmental influence on these characters is less.

- The characters plant height, leaf size/leaf area, internodal length, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size showed high heritability coupled with high genetic advance. So these characters are controlled by additive gene action and therefore amenable to genetic improvement through selection.

- Correlation studies revealed that plant height showed significant positive phenotypic correlation with leaf size/leaf area, internodal length, total Anthocyanin content, spadix length, number of flowers per spadix and life of spadix. Plant height also showed positive genotypic correlation with most of the characters. The genotypic correlation between characters helps to differentiate the vital association useful in breeding from non-vital ones.

- The environmental correlations was absent for all the characters except number of leaves/spadices per plant with spathe size indicating the influence of environment on this character.

- Number of flowers per spadix had significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, spadix length, total anthocyanin content, life of spadix, pollen fertility and pollen size. This indicates that the improvement of the

character number of flowers per spadix will result in overall increase in all the positively correlated characters. Spadix length had significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, number of flowers per spadix, life of spadix and pollen size while it showed significant negative correlation with days to initiation of female phase. Days to initiation of female phase exhibited significant negative correlation with plant height, leaf size/leaf area, spadix length and pollen fertility.

- All most all characters except number of leaves/spadices per plant, days from emergence to maturity of leaves and inclination of candle with the spathe are significantly correlated with each other at phenotypic and genotypic level.

- A study of six qualitative characters such as colour of young leaf and petiole, spathe colour, spathe texture, candle colour and type of inflorescence axis also showed considerable variation among the genotypes studied.

- The character spadix length, plant height, leaf size and life of spadix had high positive direct effect on number of flowers per spadix and 27 per cent of variation in flower production was attributed by the environment. From the present study it is evident that spadix length, plant height and leaf size/ leaf area are more associated with the dependent variable i.e., number of flowers per spadix

- Following Mahalanobis D^2 statistic the 40 genotypes were grouped into seven clusters. The maximum number of genotypes (17) were included in Cluster I, followed by cluster II (7), cluster III (5), cluster IV (5) and cluster V (4). Clusters VI and VII had one genotype each. Maximum divergence was shown between the Clusters II and VI, while the minimum divergence between clusters I and II. The intracluster distance was highest for the Cluster II. Among the 13 characters considered, life of spadix contributed maximum towards divergence followed by days to

initiation of female phase. Grouping of genotypes into different clusters did not reflect the geographical origin of the varieties.

- Selection index for the genotypes was computed on the basis of 13 characters namely, Plant height, leaf size/leaf area, internodal length, days from emergence to maturity of inflorescence, spathe size, total anthocyanin content, Spadix length, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, pollen fertility and pollen size. The maximum selection index value obtained for Liver Red followed by PR x LR and PR x DT (1) and minimum estimates were recorded for Rembolina, W x LJ and Corolix. The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the D^2 analysis.

- Intervarietal hybridization was done to analyse the cross compatibility between 15 genotypes based on the percentage of candles bearing fruits, fruit set and seed germination.

- A total of 127 crossings were attempted based on the availability of receptive spadices and fresh pollen, out of which 80 were found to be successful. In almost all cross combinations the percentage of candles bearing fruits ranged from 50 to 100 per cent. Among the 15 genotypes, the maximum percentage of candles bearing berries was obtained for PR x OG (90.00 per cent) followed by AW (66.67 per cent) and PR x LR (65.00 per cent). The lowest value 5 per cent was obtained for Esmeralda and 11.11 per cent for Dragon's Tongue.

- The number of fruits per candle ranged from 5 in Esmeralda x (PR x OG) to 85 in (PR x OG) x (OG x DT). The crosses LR x DT (83), (OG x DT) x (PR x OG) (80), LR x FR (72) and (PR x OG) x DT (70) also recorded higher number of fruits per candle. The average number of fruits per candle was highest for Liver Red (71.67) and lowest for Esmeralda (5.00). The percentage of fruit set was below 50 per cent for all the

crosses. The lowest and highest percentage of fruit set was observed for Ceasor Violet and 'Liver Red respectively.

- The berries obtained from different cross combinations took 4.5 to 7 months to mature. The number of days for germination varied from 4 to 9 days in various crosses. Most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross FR x LR. Among single seeded berries maximum seed size was for AW x (PR x OG) (4.17 x 3.45 mm). In a berry largest seed among the two seeded berries were observed for the crosses AW x (PR x OG) (3.53 x 2.27 mm) followed by [(PR x LR) x (PR x DT (2)] (3.53 x 2.25 mm). The seeds obtained from most of the crosses showed germination except three crosses *i.e.,* DT x LR, (KR x LR) x LJ and Esmeralda x (PR x OG) did not germinate at all. Percentage of germination was lowest in [PR x DT (2)] x LJ (19.05 per cent) and highest in (PR x LR) x C (71.67 per cent).

- Seedlings of 57 out of 73 crosses that germinated survived for more than four months. The seedling survival percentage ranged from 38.46 per cent in LJ x (PR x OG) to 81.25 per cent in (KR x LR) x DT. The highest average survival was recorded by Liver Red and lowest was recorded for the genotype Lady Jane.

- Compatibility parameters estimated based on the performance of the fifteen genotypes as pollen parents. Highest percentage of candles bearing fruits was shown by PR x OG followed by Fla Red, Dragon's Tongue and PR x LR. Lowest percentage were recorded for Flirt and KR x LR. Number of fruits per candle was the highest for the genotype PR x DT (2) followed by PR x OG, Dragon's Tongue and Acropolis white. In Lady Jane, Flirt and KR x LR the number of fruits were relatively lower. Higher percentage fruit set was observed for the genotypes Dragon's Tongue while it was lowest in Lady Jane. Percentage of seed germination was the highest for Fla Red and lowest for Lady Jane.

- Scoring of the compatibility reactions was done based on the percentage of fruiting candles, fruit set and seed germination on a scale ranging from zero to nine. After scoring the different genotypes, the crosses with highest compatibility score was for the crosses (PR x OG) x (OG x DT), (PR x LR) x C, FR x DT, AW x (PR x OG), (OG x DT) x (PR x OG), (PR x LR) x (PR x OG),PR x DT (2) x (PR x OG), (OG x DT) x LR, LJ x LR, (PR x OG) x DT, (PR x OG) x LR, (PR x OG) x (PR x LR) and (PR x LR) x FR. So these were the most compatible crosses. The performance of the variety as female parent was found to be different from its performance as male parent. The female parents PR x OG, PR x LR, Lady Jane, OG x DT and PR x DT (2) got the high varietal scores. Among male parents PR x OG, DT, OG x DT, FR and PR x LR got the high varietal scores. So PR x OG, OG x DT and PR x LR could be judged as the best male as well as female parents.

- Among the seedlings of the successful crosses maximum number of days for maturity of leaves was taken by the cross LJ x (PR x LR) followed by [(KR x LR) x (PR x LR)] and the least number of days was taken by C x (PR x OG). Number of leaves ranged from 4.50 in DT x FR to 6.33 in [(PR x OG) x (OG x DT)]. The leaf area was maximum for the cross LR x FR and it was minimum for LJ x (PR x OG). The colour of young leaf showed a range from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green.

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* Original not seen

CROSS COMPATIBILITY ANALYSIS FOR PRODUCTION OF HYBRIDS IN *Anthurium andreanum* Linden

MADHU KUMAR, K.

Abstract of the
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Faculty of Agriculture
Kerala Agricultural University, Thrissur

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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695 522

ABSTRACT

The present study, 'Cross compatibility analysis for production of hybrids in *Anthurium andreanum* Linden' was undertaken to identify suitable parents with commercial qualities and to determine the cross compatibility among the selected parents in anthurium. The present investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2006-2009.

The analysis of variance revealed significant variation among the 40 genotypes for the eighteen characters studied. This reveals the high genetic potential for the improvement in this crop.

Variability studies indicated high phenotypic and genotypic coefficients of variation for the characters for anthocyanin content, pollen fertility, leaf size/leaf area, spathe size and spadix length. The high heritability coupled with high genetic advance values were found for characters plant height, leaf size/leaf area, internodal length, spathe size, total anthocyanin content, spadix length, inclination of candle with spathe, number of flowers per spadix, life of spadix, days to initiation of female phase, days to inter phase, duration of male phase, pollen fertility and pollen size. These characters are therefore controlled by additive gene action and amenable to genetic improvement through selection.

Pollen fertility estimated using acetocarmine method indicated that most of the genotypes had low fertility values. Liver Red had the highest pollen fertility of 43.01 per cent followed by Lady Jane (36.14 per cent). Pollen emergence was low in the months from March to June, during which the average maximum and minimum temperatures were relatively high. Pollen emergence was highest during October to December months. A study of six qualitative characters such as colour of young leaf and petiole, spathe colour, spathe texture, candle colour and type of inflorescence axis also showed considerable variation among the genotypes studied.

Plant height was found to have highly significant positive phenotypic and genotypic correlation with leaf size/leaf area, internodal length, total Anthocyanin content, spadix length, number of flowers per spadix and life of spadix. Number of flowers per spadix had significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, spadix length, total anthocyanin content, life of spadix, pollen fertility and pollen size. Spadix length had significant positive genotypic correlation with plant height, leaf size/leaf area, internodal length, spathe size, number of flowers per spadix, life of spadix and pollen size. Days to initiation of female phase exhibited significant negative correlation with plant height, leaf size/leaf area, spadix length and pollen fertility. The environmental correlations were absent for almost all pairs of characters except for number of leaves/spadices per plant with spathe size.

Path analysis revealed that spadix length, plant height, leaf size and life of spadix had high positive direct effect on number of flowers per spadix. Mahalanobis D^2 analysis clustered the 40 genotypes into seven clusters. The maximum number of genotypes (17) were included in Cluster I, followed by cluster II (7), cluster III (5), cluster IV (5) and cluster V (4). Clusters VI and VII had one genotype each. Maximum divergence was shown between the Clusters II and VI, while the minimum divergence between clusters I and II. The intracluster distance was highest for the Cluster II. Among the 13 characters considered, life of spadix contributed maximum towards divergence followed by days to initiation of female phase. Grouping of genotypes into different clusters did not reflect the geographical origin of the varieties.

Selection index analysis revealed that genotype Liver Red attained the maximum selection index value followed by PR x LR and PR x DT (1) and the minimum estimates were recorded for Rembolina, W x LJ and Corolix. The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the D^2 analysis.

Intervarietal hybridization was done to analyse the cross compatibility between 15 genotypes based on the percentage of candles bearing fruits, fruit set and seed germination.

A total of 127 crosses were attempted based on the availability of receptive spadices and fresh pollen, out of which 80 were found to be successful. In almost all cross combinations the percentage of candles bearing fruits ranged from 50 to 100 per cent. Among the 15 genotypes, the maximum percentage of candles bearing berries was obtained for PR x OG (90.00 per cent) followed by AW (66.67 per cent) and PR x LR (65.00 per cent). The lowest value 5 per cent was obtained for Esmeralda and 11.11 per cent for Dragon's Tongue.

The number of fruits per candle ranged from 5 in Esmeralda x (PR x OG) to 85 in (PR x OG) x (OG x DT). The crosses LR x DT, (OG x DT) x (PR x OG) , LR x FR and (PR x OG) x DT also recorded higher number of fruits per candle. The average number of fruits per candles was highest for Liver Red and lowest for Esmeralda. The percentage of fruit set was below 50 per cent for all the crosses. The lowest and highest percentage of fruit set was observed for Ceasor Violet and 'Liver Red respectively.

The berries obtained from different cross combinations took 4.5 to 7 months to mature. Most of the crosses had a high percentage of single seeded berries compared to double seeded berries except for the cross FR x LR. Among single seeded berries maximum seed size was for AW x (PR x OG). In a berry largest seed among the two seeded berries were observed for the crosses AW x (PR x OG) followed by [(PR x LR) x (PR x DT (2)]. The number of days taken for germination varied from four to nine days. The seeds obtained from most of the crosses showed germination except three crosses *i.e.,* DT x LR, (KR x LR) x LJ and Esmeralda x (PR x OG) did not germinate at all. Percentage of germination was lowest in [PR x DT (2)] x LJ and highest in (PR x LR) x C.

Seedlings of 57 out of 73 crosses that germinated survived for more than four months. The seedling survival percentage ranged from 38.46 per cent in LJ x (PR x OG) to 81.25 per cent in (KR x LR) x DT. The highest average survival was recorded by Liver Red and lowest was recorded for the genotype Lady Jane.

Compatibility parameters estimated based on the performance of the fifteen genotypes as pollen parents. Highest percentage of candles bearing fruits was shown by PR x OG followed by Fla Red, Dragon's Tongue and PR x LR. Lowest percentage were recorded for Flirt and KR x LR. Number of fruits per candle was the highest for the genotype PR x DT (2) followed by PR x OG, Dragon's Tongue and Acropolis white. In Lady Jane, Flirt and KR x LR the number of fruits were relatively lower. Higher percentage fruit set was observed for the genotypes Dragon's Tongue while it was lowest in Lady Jane. Percentage of seed germination was the highest for Fla Red and lowest for Lady Jane.

Scoring of the compatibility reactions based on the percentage of fruiting candles, fruit set and seed germination on a scale ranging from zero to nine. After scoring the different genotypes, the crosses with highest compatibility score was for the crosses (PR x OG) x (OG x DT), (PR x LR) x C, FR x DT, AW x (PR x OG), (OG x DT) x (PR x OG), (PR x LR) x (PR x OG),PR x DT (2) x (PR x OG), (OG x DT) x LR, LJ x LR, (PR x OG) x DT, (PR x OG) x LR, (PR x OG) x (PR x LR) and (PR x LR) x FR. So these were the most compatible crosses. The performance of the variety as female parent was found to be different from its performance as male parent. The female parents PR x OG, PR x LR, Lady Jane, OG x DT and PR x DT (2) got the high varietal scores. Among male parents PR x OG, DT, OG x DT, FR and PR x LR got the high varietal scores. So PR x OG, OG x DT and PR x LR could be judged as the best male as well as female parents.

Among the seedlings of the successful crosses maximum number of days for maturity of leaves was taken by the cross LJ x (PR x LR) and the least number of days was taken by C x (PR x OG). Number of leaves ranged from 4.50 in DT x FR to 6.33 in [(PR x OG) x (OG x DT)]. The leaf area was maximum for the cross LR x FR and it was minimum for LJ x (PR x OG). The colour of young leaf showed a range from brown to reddish brown to greenish brown to green. The colour of petiole also varied from brown to reddish brown to greenish brown to green.